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Technical Note

No. 166

Boulder Laboratories

AN ATLAS OF WHISTLERS AND VLF EMISSIONS

A SURVEY OF VLF SPECTRA FROM BOULDER, COLORADO

BY

D. L. JONES, R. M. GALLET,

J. M. WATTS, D. N. FRAZER

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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NATIONAL BUREAU OF STANDARDS

Technical Note

166

JANUARY 1963

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by

D. L. Jones, R. M. Gallet, J. M. Watts, D. N. Frazer
National Bureau of Standards, Boulder, Colorado

ABSTRACT

Naturally occurring VLF noises are classified and spectrograms illustrating each class are presented.

The report is divided into six sections. The first section consists of the systematic classification of VLF noises. Samples of whistlers and VLF emissions are shown in the second and third sections, respectively. The next section gives examples of interactions between these two classes. Section five consists of some exceptionally active periods during magnetic disturbances. The last section is a synoptic survey for the four months, March through June, 1957. A spectrogram is given for every observation period containing any VLF activity.

Most of the data was recorded at the Sunset Field Station of the National Bureau of Standards, Boulder, Colorado, during 1956-1957.

TABLE OF CONTENTS

INTRODUCTION

SECTION I - SYSTEMATIC CLASSIFICATION OF VLF NOISES 1
VLF Noise Classification 2
Classes of Discrete VLF Emissions 3

SECTION II - WHISTLERS 4
Long Whistler with Twenty-one Separate Echoes 5
Multiple Echo Whistler 6
Whistlers Extending to Low Frequencies 7
Whistler Train with a Very Long Dispersion 8
Nose Whistlers 9
Dispersion Analysis of Whistlers 11
(Distinction made between multiple path and multiple flash)

SECTION III - VLF EMISSIONS 17
Transition in the Slope of Hooks 18
Rising Tones 19
Rising Tones as Possible Degenerate Forms of Hooks 20
Chorus 21
Falling Tones 22
Quasi-Horizontal Tones 23
Pseudo Noses 24
Complex Events 25
Emission with a Train of Echoes 26
Echoing VLF Emission 27
Hiss 28
Transition from Hiss to Detailed Structure 30

SECTION IV - INTERACTIONS BETWEEN WHISTLERS AND VLF EMISSIONS 31
Risers Following a Whistler 32
Whistlers Followed by VLF Emissions 33
Hiss Triggered by a Whistler 34
Interactions 35

SECTION V - PERIODS SELECTED FOR THEIR VLF ACTIVITY 36
Events of 16-17 May 1956, associated with strong magnetic disturbance. Maximum K_p = 8+ 37
Events of 16 September 1956, associated with weak magnetic disturbance. Maximum K_p = 3° 48
Events of 25-26 October 1956, associated with moderate magnetic disturbance. Maximum K_p = 7- 50
Events of 9-14 November 1956, associated with moderate magnetic disturbance. Maximum K_p = 7- 56
Events of 30 June 1957, associated with strong magnetic disturbance. Maximum K_p = 8+ 62
Events of 12 February 1958, associated with strong magnetic disturbance. Maximum K_p = 9° 65

SECTION VI - FOUR-MONTH SYNOPTIC SURVEY OF VLF NOISES 66

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National Bureau of Standards, Boulder, Colorado

INTRODUCTION

It is the purpose of this atlas to present a comprehensive survey of the very low frequency (VLF) activity observed at a middle latitude station (Boulder, Colorado--geomagnetic latitude 40° N). The period covered is the year and one-half beginning in January 1956 and ending in June 1957; the period just prior to and in preparation for the International Geophysical Year (IGY). The two major groups of VLF activity, whistlers and VLF emissions, are shown in considerable detail, as well as a third rarer group consisting of whistler-VLF emission interactions. Certain periods of VLF activity associated with disturbances of the earth's magnetic field are also presented. The work which led to the material presented here was probably the first systematic study, with records and spectrograms of sufficiently good quality, of the characteristics of VLF emissions. It was principally on the basis of the data in this atlas that a classification of the types of VLF noises was developed [1,2]. This classification was important for organizing the observational program during the IGY.

A program of observation of whistlers and VLF emissions was initiated at the Boulder Laboratories of the National Bureau of Standards early in 1955. The equipment to detect and record these natural VLF noises was developed and installed in the summer of 1955 at the Sunset Field Site (40° 08' N, 254° 42' E). The equipment design was similar to that used in the subsequent IGY whistler program [3] with the exception of the antenna which was a loop with an area of approximately 110,000 m^2.

The recording of a single spectrogram takes about five minutes and on the 0-8 kc/s display, represents only 2.4 seconds of data. Thus, if one entire two minute period were printed it would take about five hours. To complete a 24 hour day in this manner would require about one month. While it would be possible to operate a large number of spectrographs and obtain visual records of all the data, such a process would be extremely time-consuming and costly. However, this is not necessary since some recording periods contain no VLF events while others contain several. For instance, in the first half of 1957 a total of 4041 two-minute periods were recorded of which 137 contained discrete VLF emissions, and 255 contained hiss. Whistlers occurred at the average rate of 2.24 per minute throughout the year. Subsequent experience has shown that this does not represent an exceptionally high level of VLF activity.

By January 1956, the observation program was on a regular basis with magnetic tape samples being taken during two minutes of each hour. The magnetic tapes were then monitored aurally and dynamic spectrograms of the selected events were obtained with a sound spectrograph. The data are displayed with frequency in ordinate and time in abscissa. Normally, the frequency range 0-8 kc/s is examined, but in some special cases, the ranges 0-4 kc/s, 0-16 kc/s, and 0-32 kc/s are studied (in this atlas, the respective frequency and time scales are indicated for each spectrogram).

A large fraction of the present material was already available

early in 1957, and a preliminary atlas was assembled and distributed in limited circulation to groups actively engaged in the preparation of VLF programs for the coming IGY. The present atlas is a more complete version of that earlier work, containing nearly three times as much data. That early period was very fruitful. As a propagation phenomenon the whistlers disclosed the extension of the outer atmosphere of the earth, and later permitted to give a reasonably accurate model of the electron density distribution to distances as large as four or five earth's radii. The VLF emissions disclosed the presence of bunches and streams of high energy electrons producing electromagnetic waves of well-defined VLF frequencies far out in the exosphere of the earth. The theory of the emission mechanism, combined with the observed characteristics, gave the first quantitative indication of the velocities and energies of the high energy particles. These discoveries were made prior to the era of direct measurements by means of the satellites and space probes which revealed the existence and structure of the Van Allen radiation belts. Using more recent and sophisticated techniques, the experimental work has uncovered a wealth of more complex VLF phenomena than those presented here, and the present authors intend to produce a specialized complementary publication dealing with these phenomena. Notwithstanding the newer developments, it is felt that this atlas can serve as a useful reference for the basic VLF phenomena.

The atlas is divided into six sections. The first section consists of the systematic classification of VLF noises. The next three sections follow the outline of the classification of VLF emissions presented in Section 1. Section 2 on whistlers contains: whistlers with multiple echoes, nose whistlers, and dispersion measurements of the several types of whistlers. Section 3, on VLF emissions illustrates in detail, various classes of discrete VLF emissions. Whistler-VLF emission interactions are presented in Section 4. Periods selected for their VLF activity which also coincide with magnetic disturbances are presented in Section 5. Section 6 gives a four-month synoptic survey of both whistlers and VLF emissions. Beginning March 2, 1957, at least one sonagram is shown for each period that contains an audible VLF noise. In addition to the samples previously classified, this section shows the typical evolution of the VLF activity over a considerable period of time.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the valuable assistance of Miss Jean Koch in the preparation of this atlas.

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2. Gallet, R. M., The very low frequency emissions generated in the earth's exosphere, Proc. IRE, 47, No. 2, pp. 211-231 (Feb. 1959).

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SECTION I

SYSTEMATIC CLASSIFICATION OF VLF NOISES

SYSTEMATIC CLASSIFICATION OF OBSERVED VLF NOISES

Two Major Groups:

I. WHISTLERS - Cause: Lightning Discharges

All frequencies emitted at once; shape due to dispersion along the path.

II. VLF EMISSIONS - Not caused by lightning.

Strongly associated with magnetic perturbations.

TWO PRINCIPAL TYPES:

1. Continuous in both time and frequency.

   Steady state situation. Hiss

2. Discrete, but often with repetition tendency

   Transient situation Many classes recognized.

A Third Rarer and More Complex Group Exists

III. Interactions between Whistlers and VLF emissions

1. Continuous

   a. Enhancement of whistler echoes with hiss

   b. Whistler triggering hiss

2. Discrete

   a. VLF emission preceding whistler

   b. VLF emission following whistler

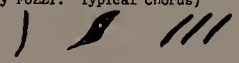
II. 2. CLASSES OF DISCRETE VLF EMISSIONS:

1. HOOKS

2. RISERS

2B. HOOK WITH EXTENDED RISING TAIL

3. QUASI VERTICAL (Generally FUZZY. Typical Chorus)



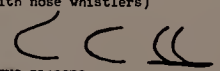
4. FALLINC TONES

4B. PSEUDO WHISTLERS

5. QUASI HORIZONTAL

SB. COMBINATION OF 4 AND 5

6. PSEUDO NOSES (by analogy with nose whistlers)



7. TOO COMPLEX FOR THE PRECEDINC CLASSES

8. EXCEPTIONAL STRONC NOISES WITH TRAIN OF ECHOES

SECTION II

WHISTLERS

LONG WHISTLER WITH TWENTY-ONE SEPARATE ECHOES

6 APRIL 1957
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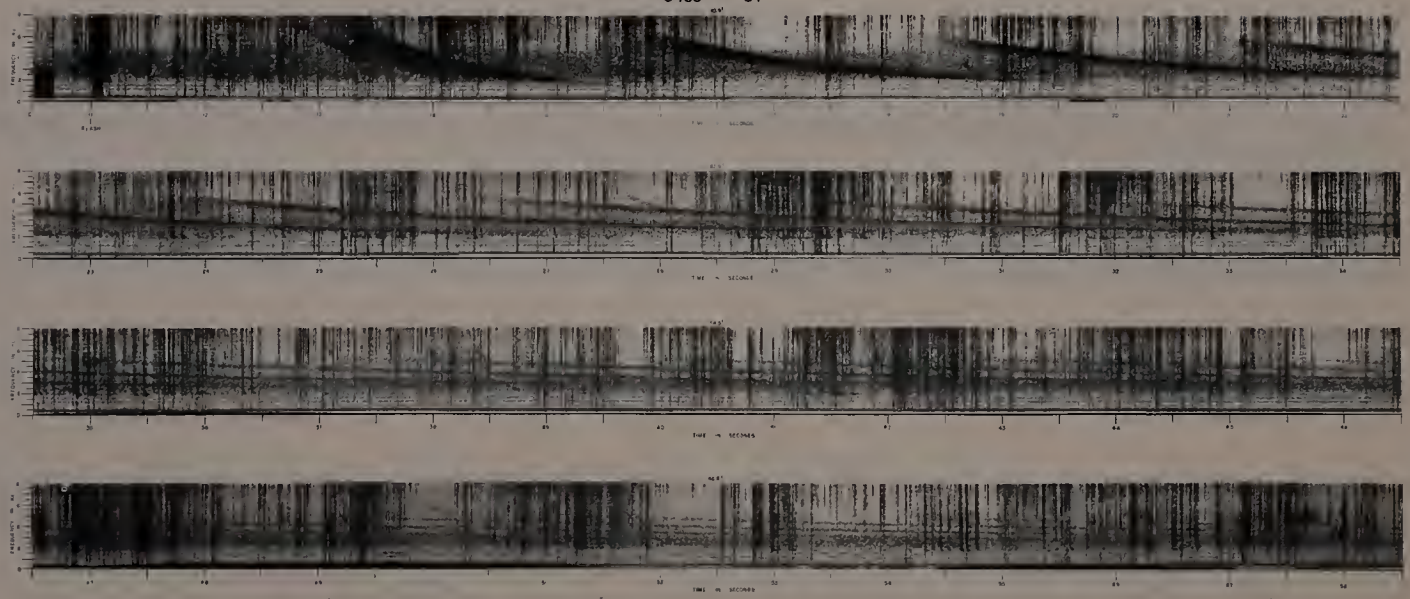
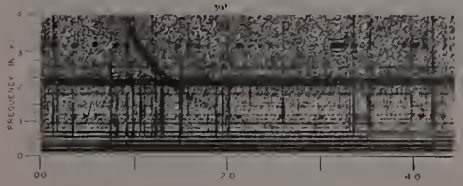


MULTIPLE ECHO WHISTLER

3 MARCH 1956
0440 UT

WHISTLERS EXTENDING TO LOW FREQUENCIES

3 JANUARY 1957
0435 UT



22 JANUARY 1957
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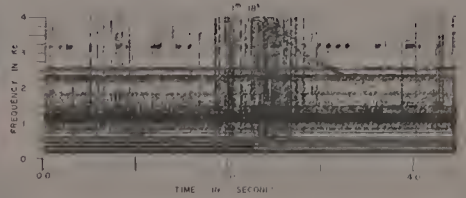
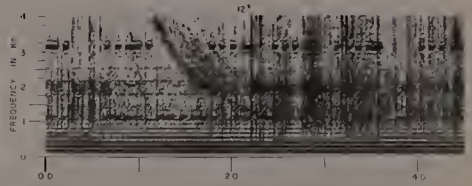


28 JANUARY 1957
0835 UT



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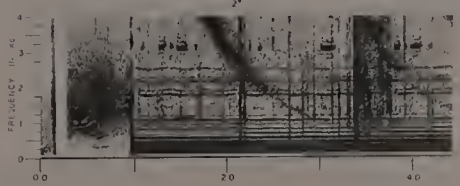

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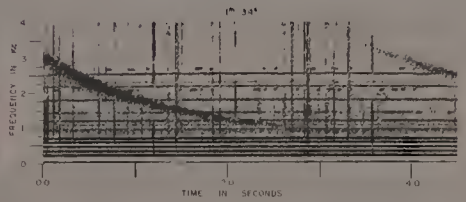

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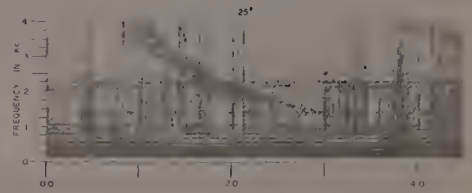

9 FEBRUARY 1957
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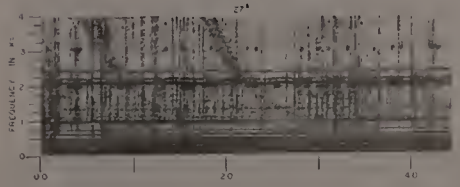

17 FEBRUARY 1957
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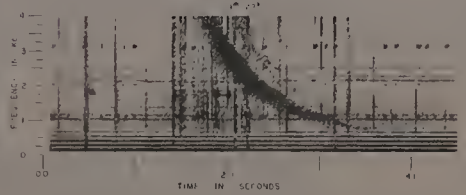

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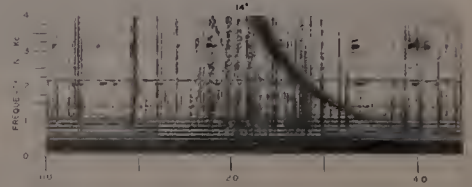
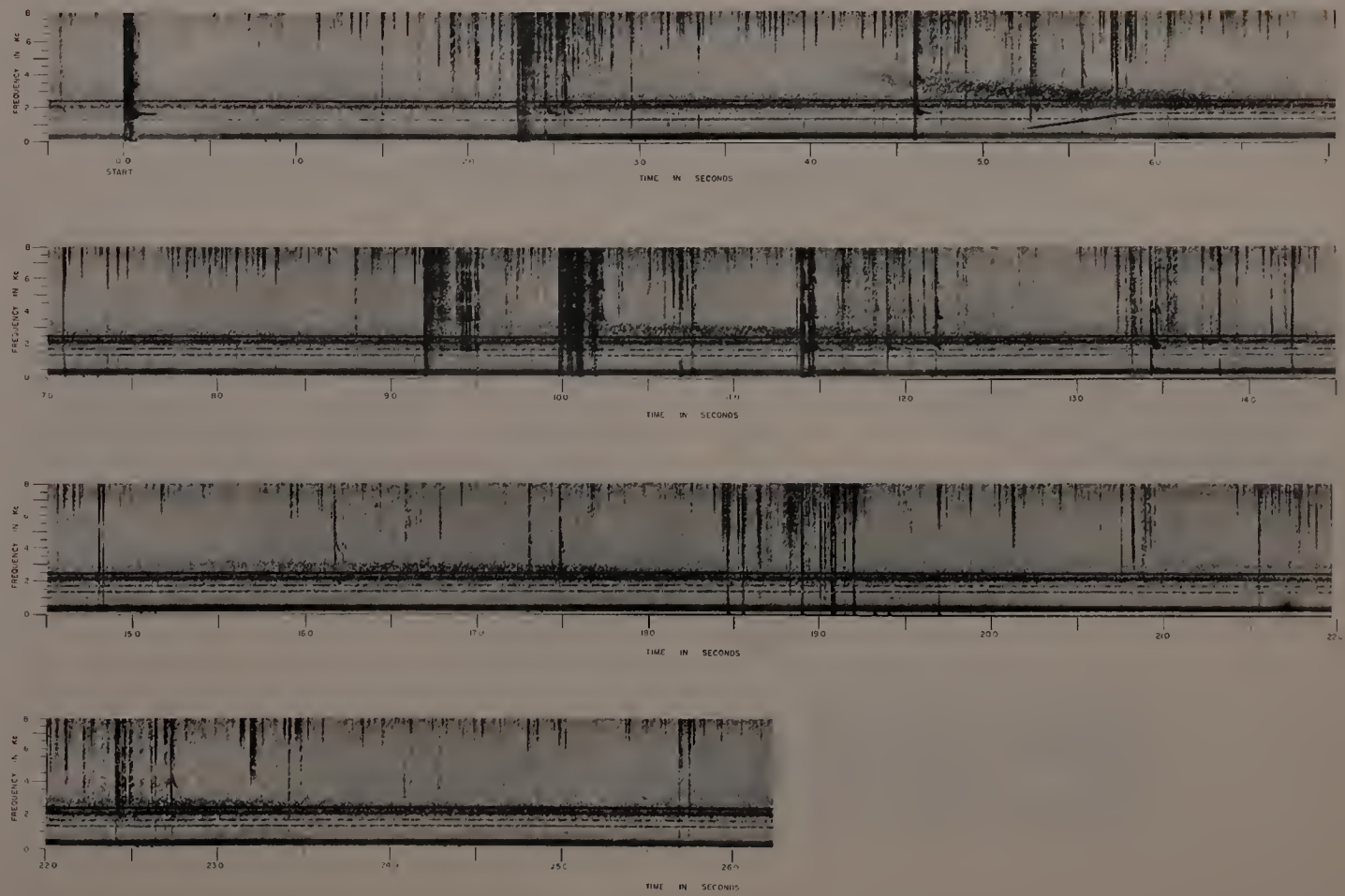


WHISTLER TRAIN WITH A VERY LONG DISPERSION (D=150)

8 DECEMBER 1956 0435 UT



NOSE WHISTLER

20 JANUARY 1957
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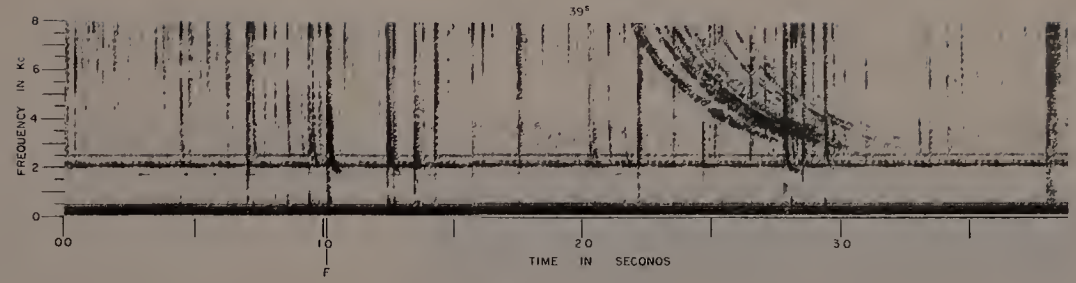

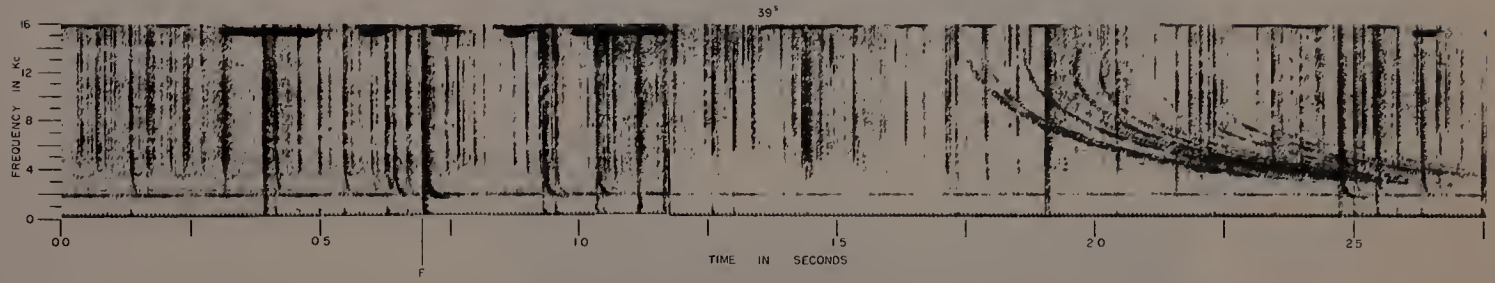

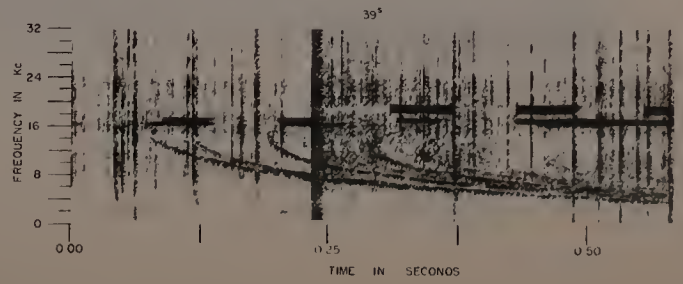

NOSE WHISTLER

25 JANUARY 1957
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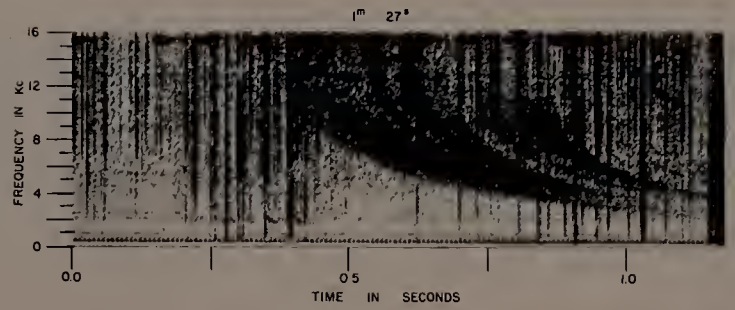

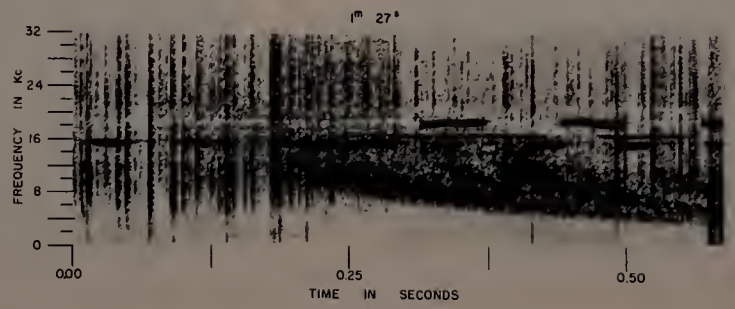

DISPERSION ANALYSIS OF WHISTLERS

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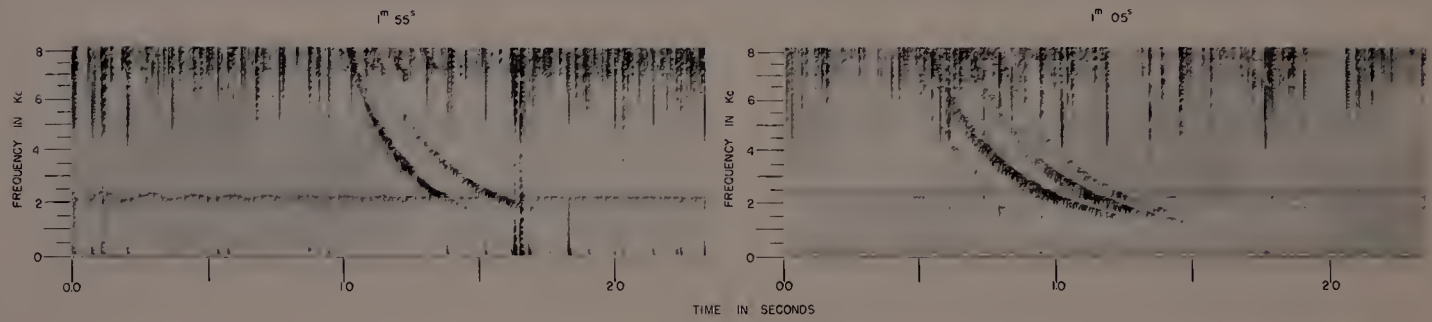

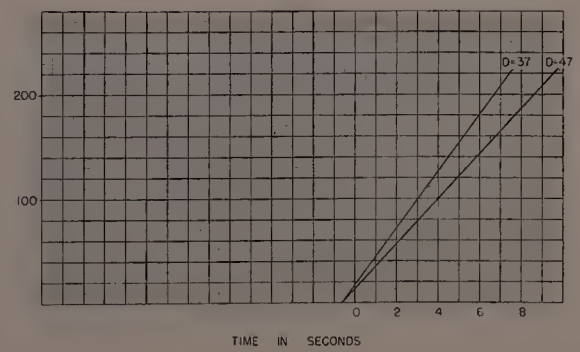

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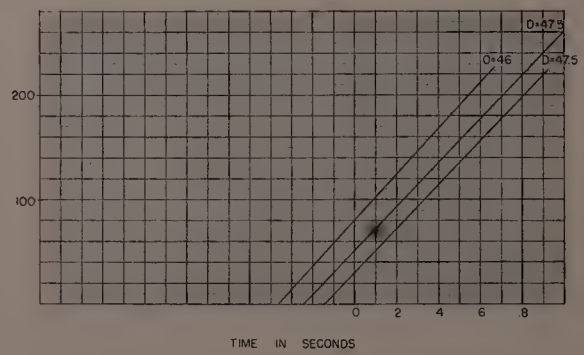

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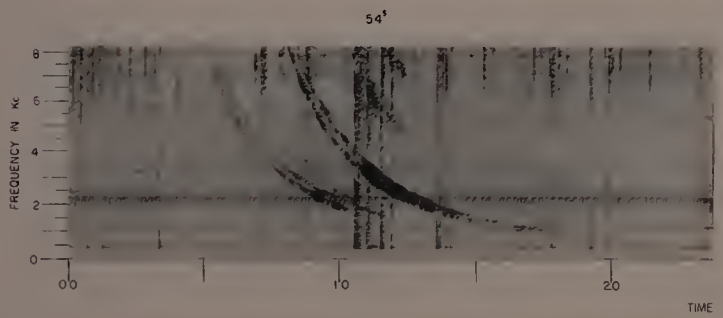

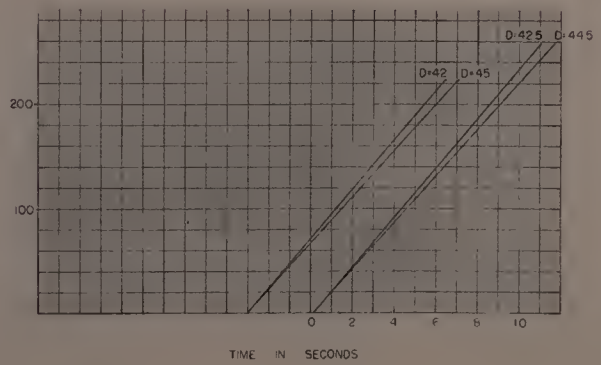

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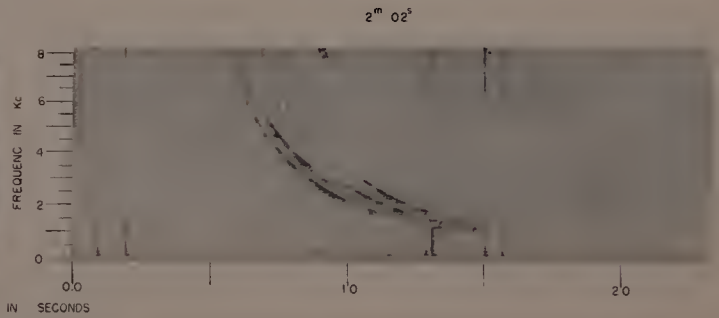

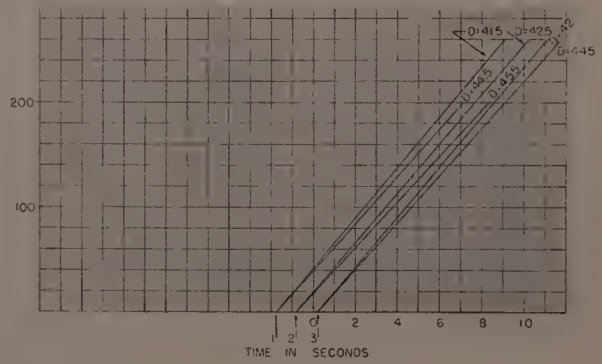

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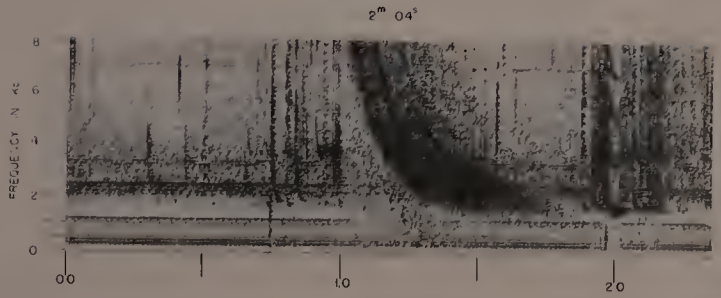

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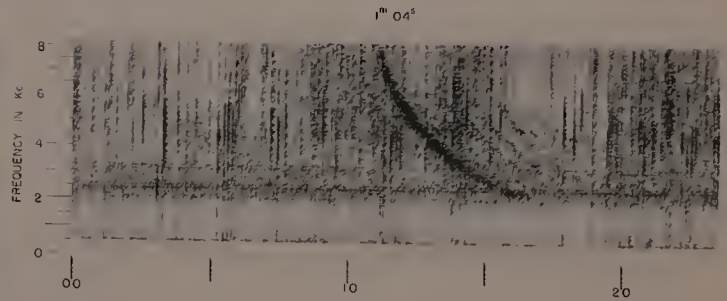

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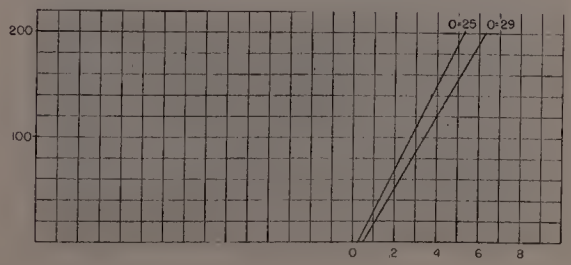

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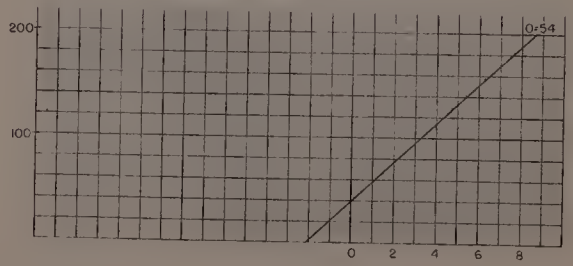
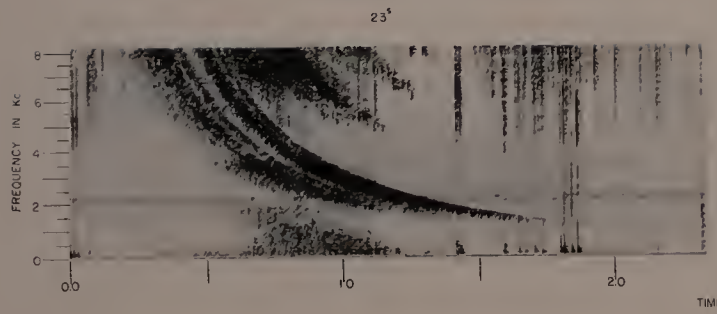
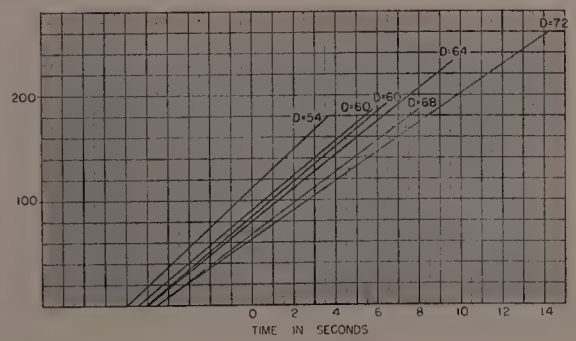


TIME IN SECONDS

TYPE SHORT

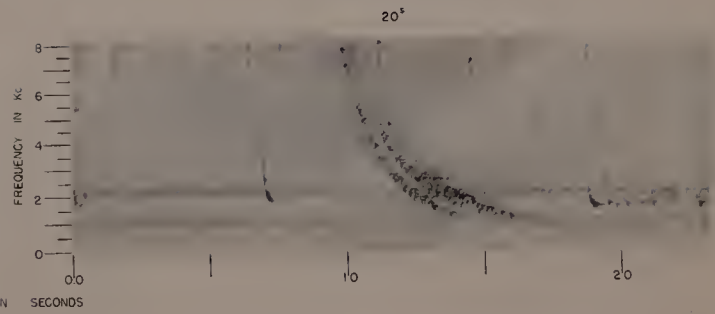
5 MAY 1956
0140 UT

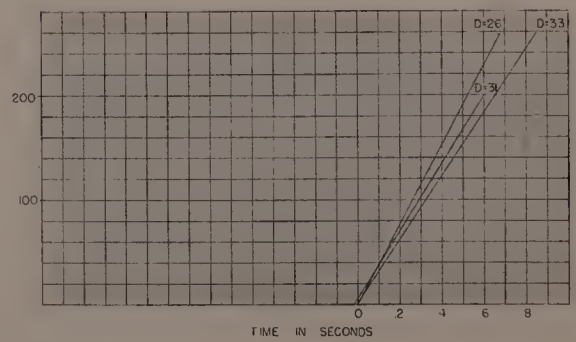




TYPE SHORT MF
MP

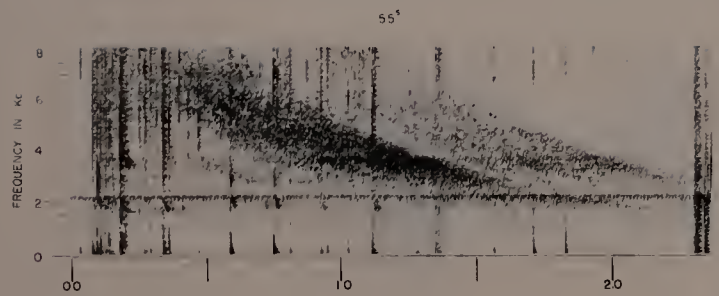
18 MAY 1956
0935 UT



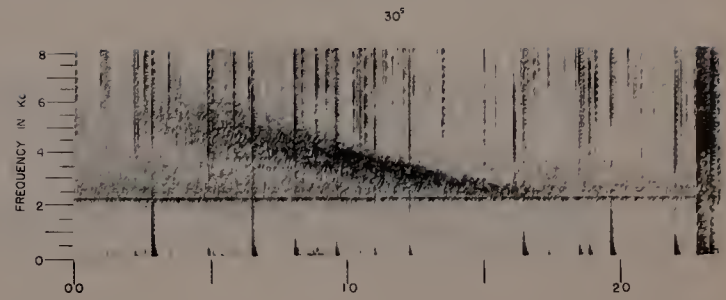


TYPE SHORT MP

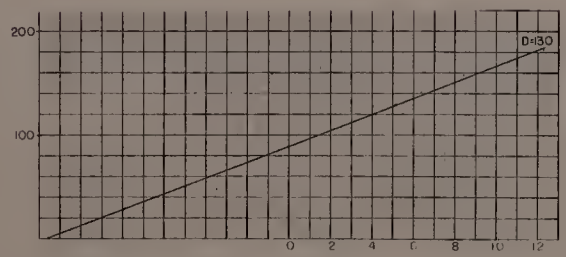
5 MAY 1956
0840 UT



5 MAY 1956
0040 UT

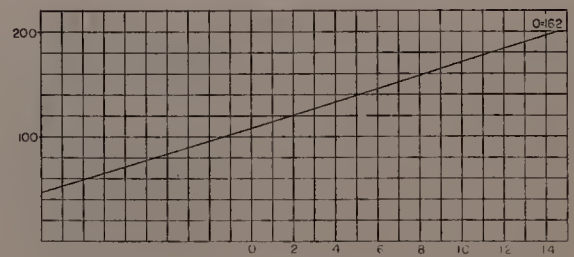


TIME IN SECONDS



TIME IN SECONDS

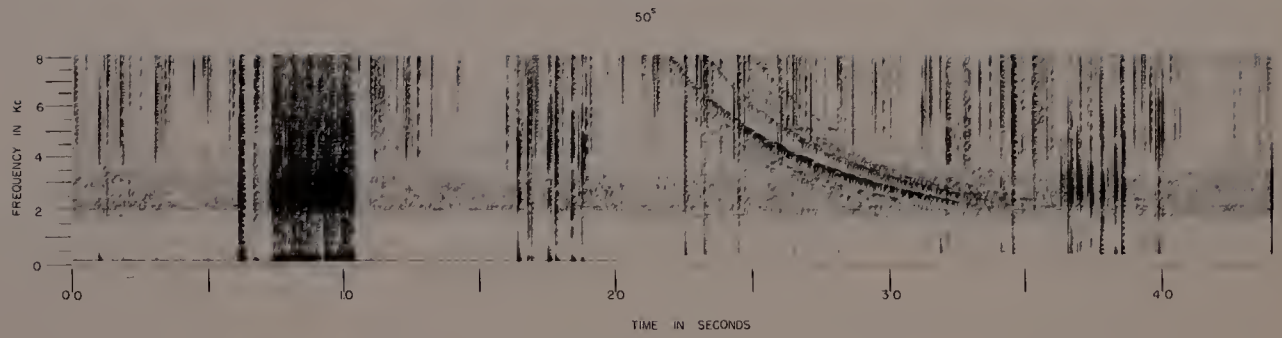
TYPE LONG

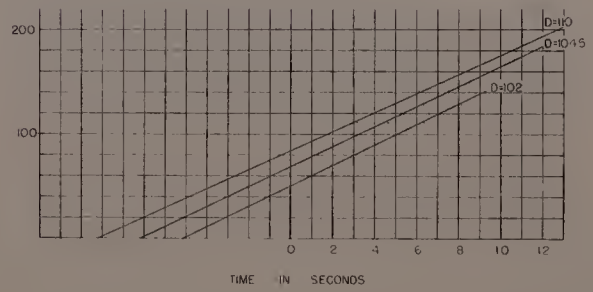


TIME IN SECONDS

TYPE LONG

25 JUNE 1956
1735 UT





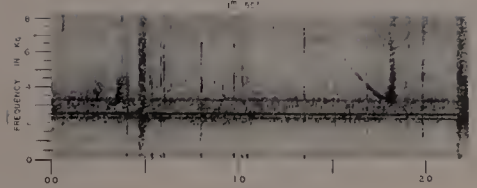
TYPE LONG MF

SECTION III

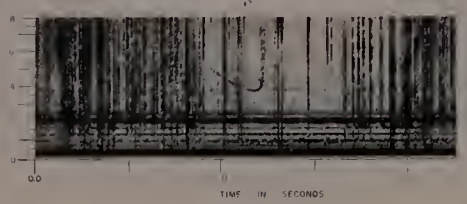
VLF EMISSIONS

TRANSITION OF THE SLOPES IN HOOKS

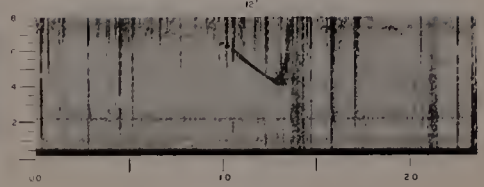
16 MAY 1956
1335 UT



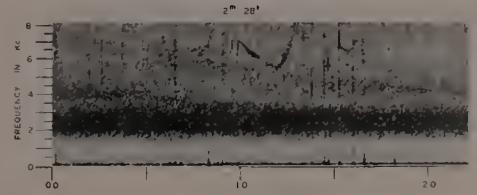
10 NOVEMBER 1956
1235 UT



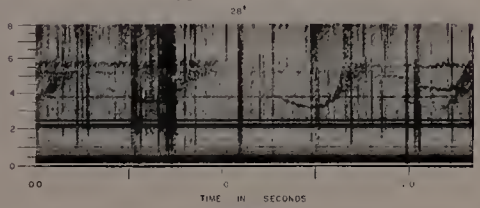
12 NOVEMBER 1956
2335 UT



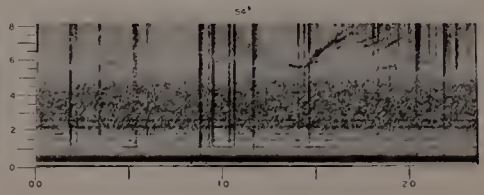
17 MAY 1956
0135 UT



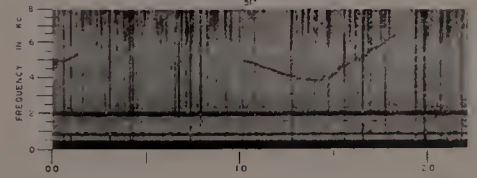
29 OCTOBER 1956
1135 UT



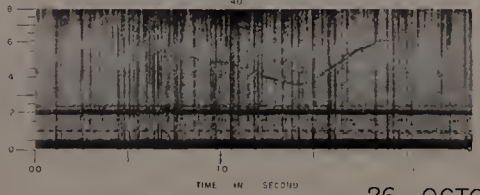
24 NOVEMBER 1956
1135 UT



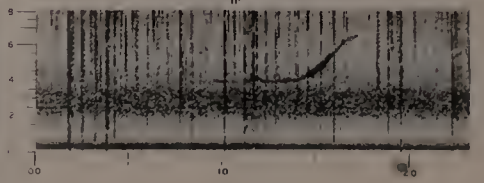
16 SEPTEMBER 1956
1835 UT



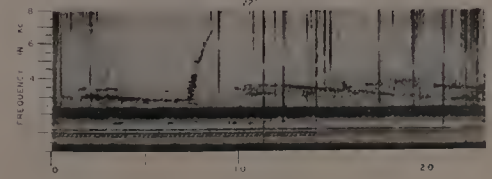
16 SEPTEMBER 1956
1835 UT



25 NOVEMBER 1956
0435 UT



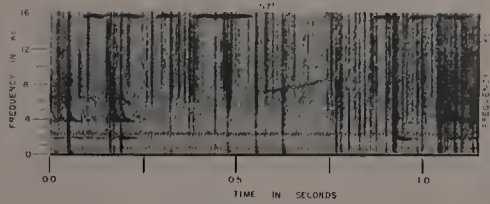
26 OCTOBER 1956
2230 UT



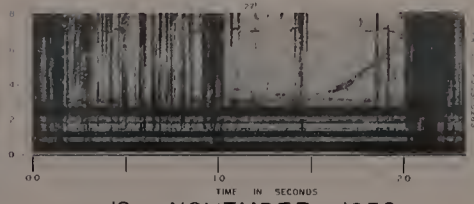
26 OCTOBER 1956
2230 UT

RISING TONES

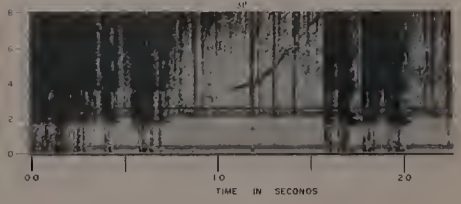
27 OCTOBER 1956
0735 UT



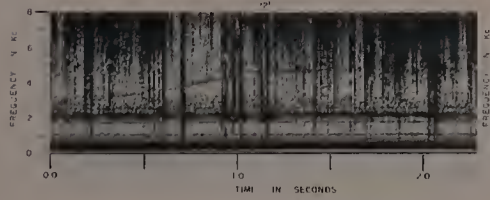
8 OCTOBER 1956
2235 UT



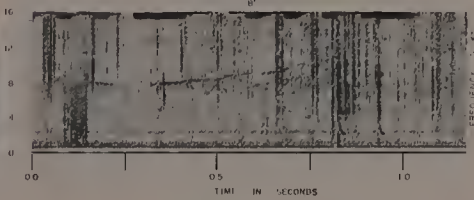
13 DECEMBER 1956
0735 UT



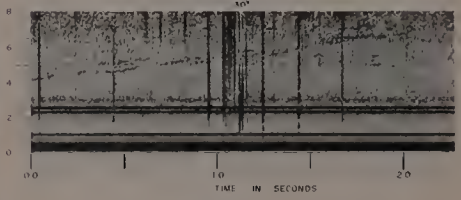
1 FEBRUARY 1957
0735 UT



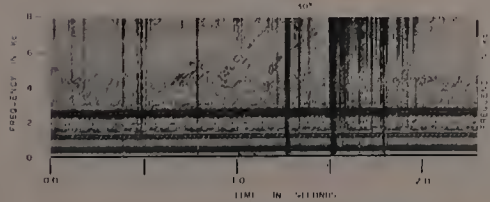
12 NOVEMBER 1956
2335 UT



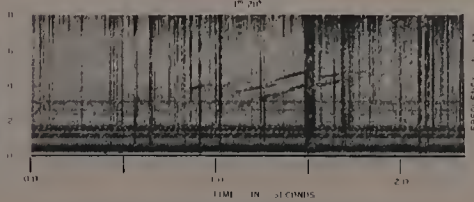
25 DECEMBER 1956
2235 UT



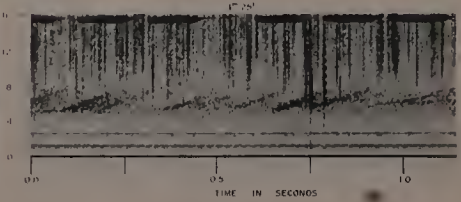
13 DECEMBER 1956
2135 UT



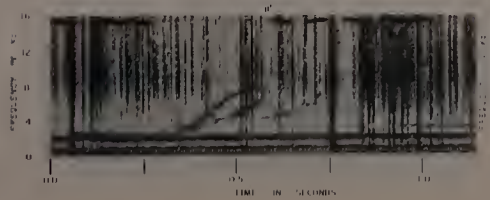
9 NOVEMBER 1956
2035 UT



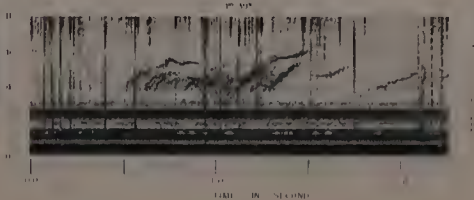
21 JANUARY 1957
1635 UT



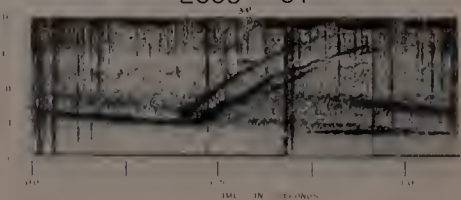
26 OCTOBER 1956
2230 UT



16 NOVEMBER 1956
2135 UT

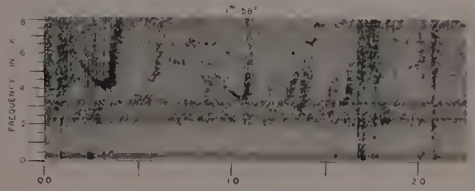


14 NOVEMBER 1956
2335 UT

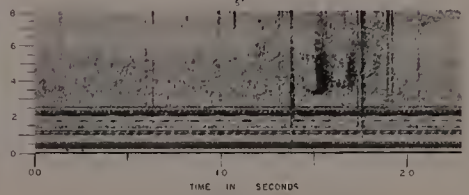


RISING TONES AS POSSIBLE DEGENERATE FORMS OF HOOKS

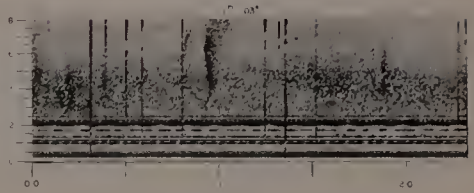
16 MAY 1956
1335 UT



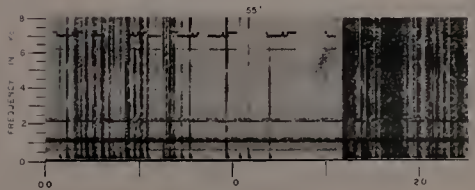
12 NOVEMBER 1956
1535 UT



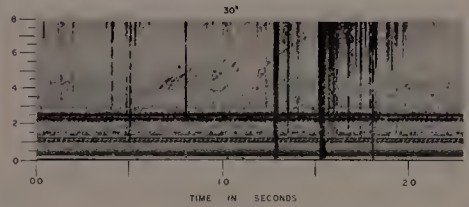
12 NOVEMBER 1956
1535 UT



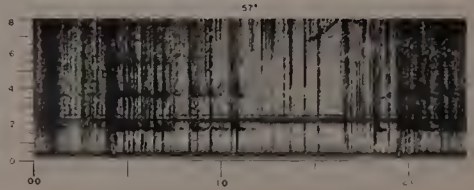
8 SEPTEMBER 1956
1435 UT



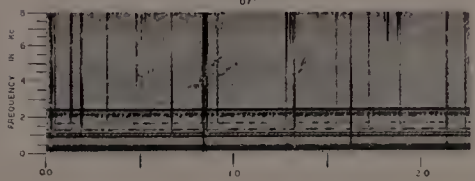
13 DECEMBER 1956
2135 UT



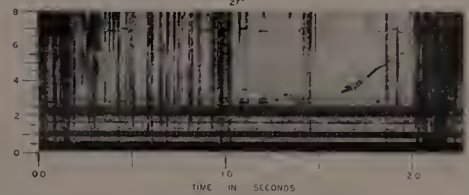
27 OCTOBER 1956
0735 UT



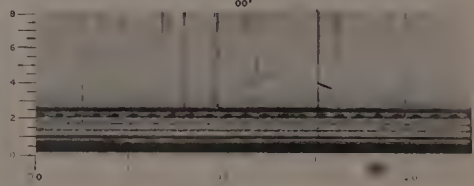
12 NOVEMBER 1956
1935 UT



8 OCTOBER 1956
2235 UT

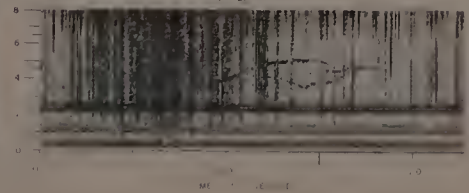


25 OCTOBER 1956
1535 UT

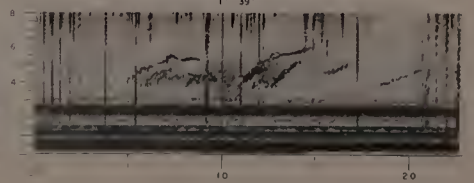


24 NOVEMBER 1956
0635 UT

20 NOVEMBER 1956
1935 UT

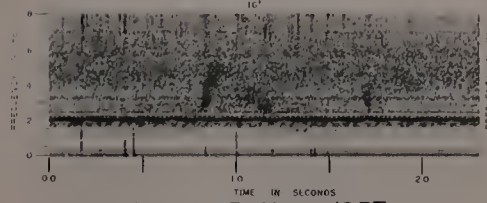


13 NOVEMBER 1956
2135 UT

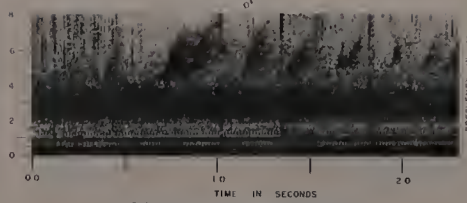


CHORUS

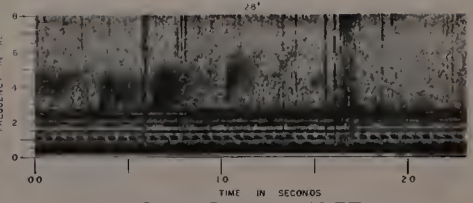
16 MAY 1956
1835 UT



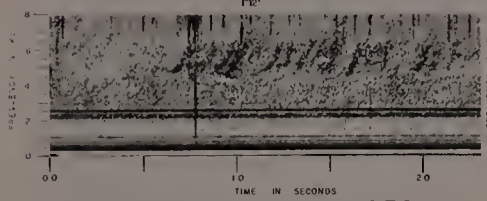
15 MAY 1956
1235 UT



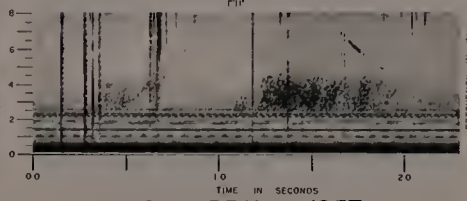
28 OCTOBER 1956
1435 UT



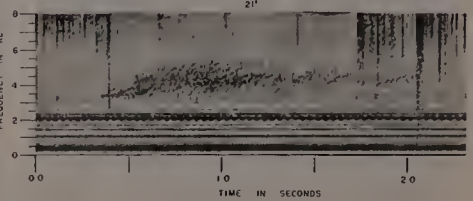
10 MARCH 1957
1235 UT



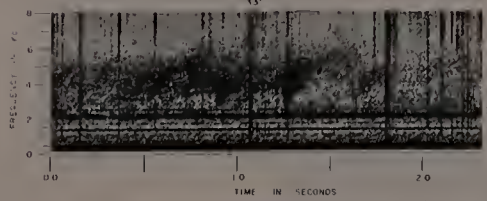
21 OCTOBER 1956
1335 UT



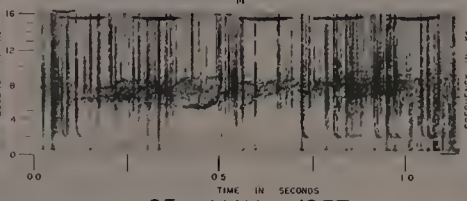
6 APRIL 1957
2335 UT



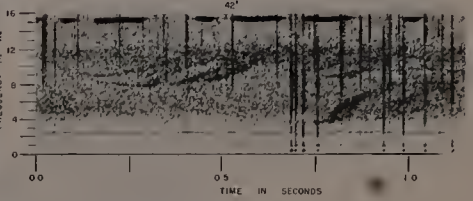
10 NOVEMBER 1956
1335 UT



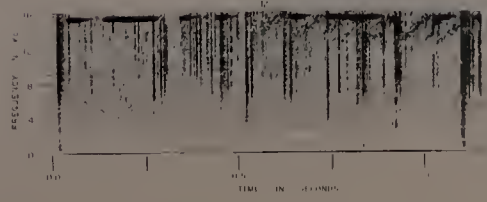
6 APRIL 1957
0135 UT



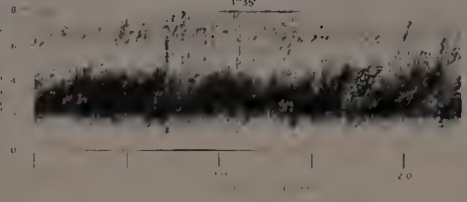
10 MARCH 1957
1435 UT



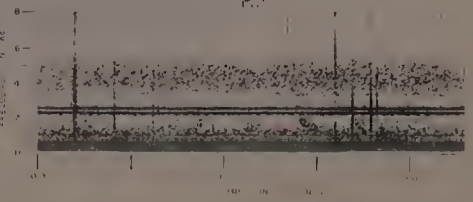
5 FEBRUARY 1957
1335 UT



25 MAY 1957
1235 UT

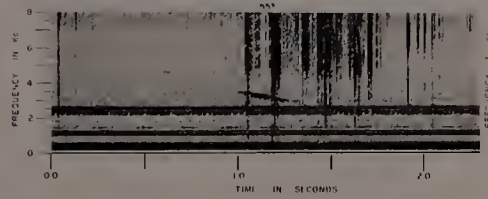


22 SEPTEMBER 1956
1635 UT

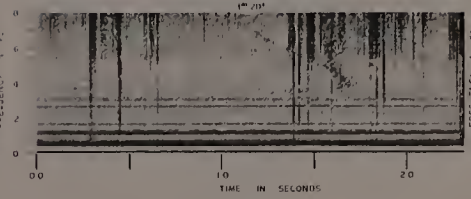


FALLING TONES

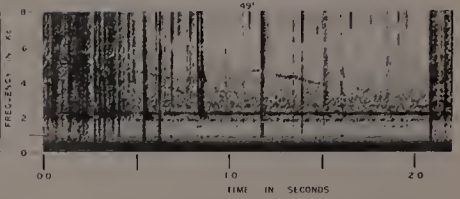
2 JANUARY 1957
2235 UT



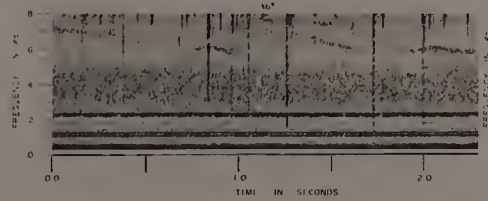
6 FEBRUARY 1957
2235 UT



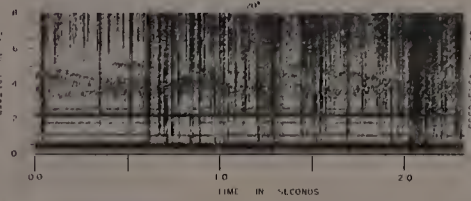
16 MARCH 1957
0535 UT



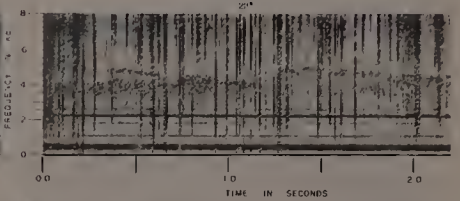
13 FEBRUARY 1957
1935 UT



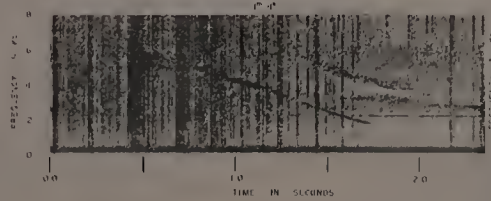
23 FEBRUARY 1957
2135 UT



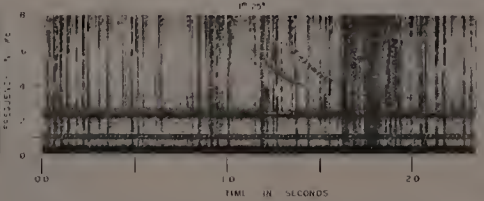
23 FEBRUARY 1957
2135 UT



14 NOVEMBER 1956
2335 UT

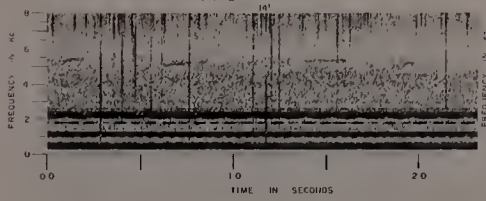


20 SEPTEMBER 1956
2035 UT

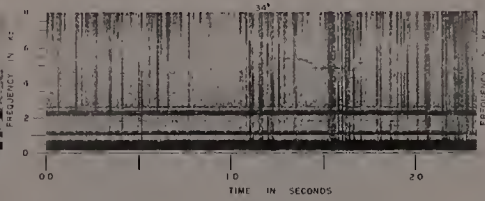


QUASI-HORIZONTAL TONES

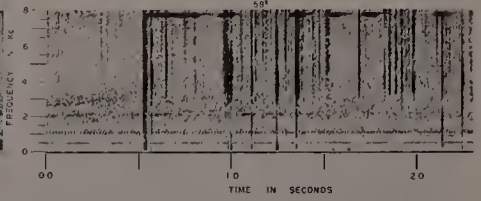
7 FEBRUARY 1957
1735 UT



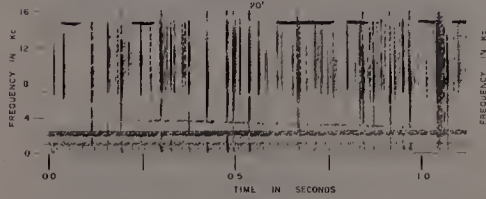
16 SEPTEMBER 1956
1835 UT



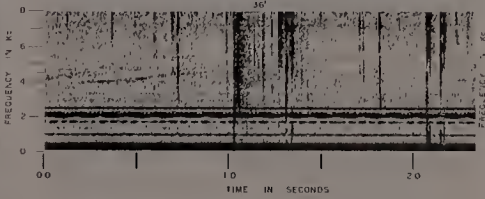
24 NOVEMBER 1956
1435 UT



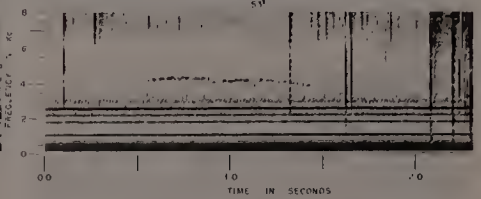
26 OCTOBER 1956
2235 UT



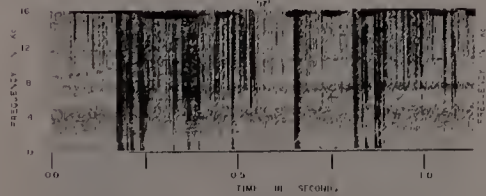
26 DECEMBER 1956
0135 UT



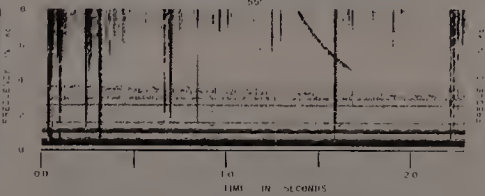
27 JANUARY 1957
2235 UT



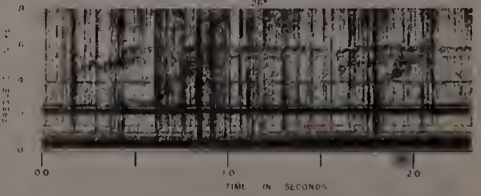
24 NOVEMBER 1956
1035 UT



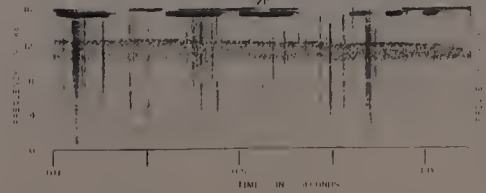
6 FEBRUARY 1957
2235 UT



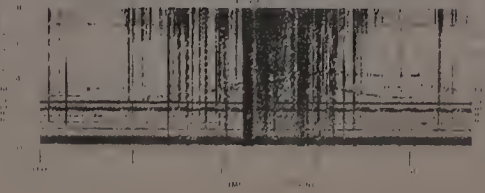
29 OCTOBER 1956
1135 UT



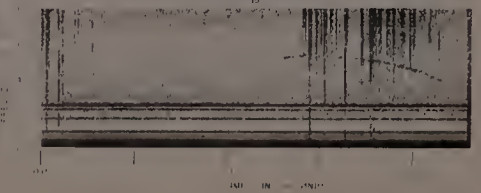
5 FEBRUARY 1957
0035 UT



20 NOVEMBER 1956
1835 UT

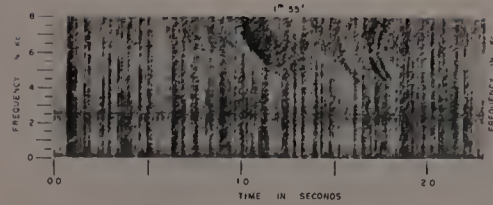


25 DECEMBER 1956
2335 UT

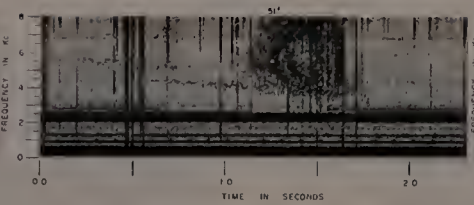


PSEUDO-NOSES

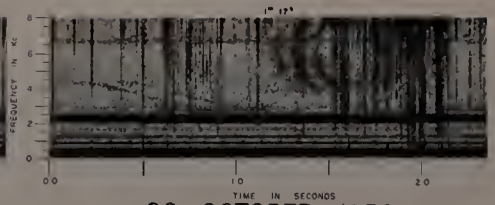
14 AUGUST 1956
1435 UT



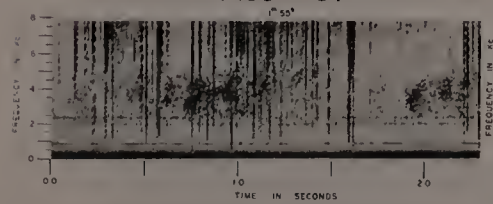
26 OCTOBER 1956
2235 UT



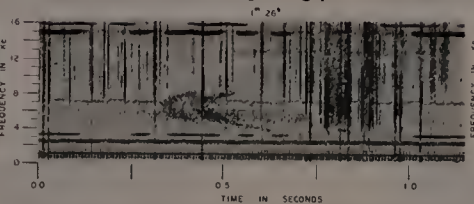
26 OCTOBER 1956
2235 UT



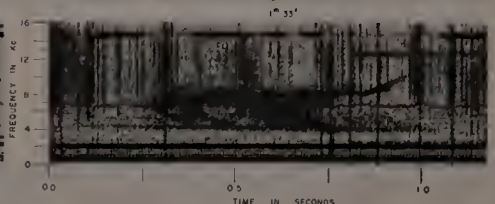
25 MARCH 1957
1235 UT



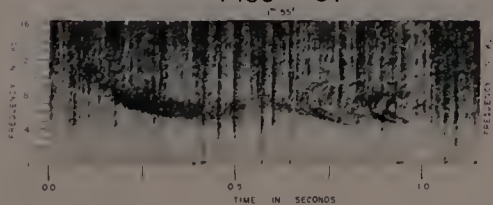
26 OCTOBER 1956
2235 UT



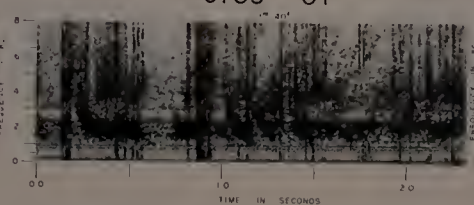
26 OCTOBER 1956
2235 UT



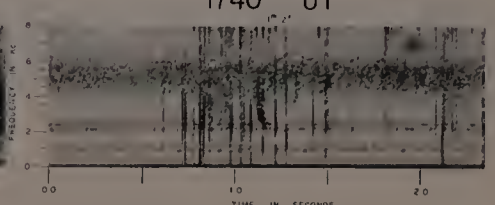
14 AUGUST 1956
1435 UT



16 MAY 1956
0735 UT

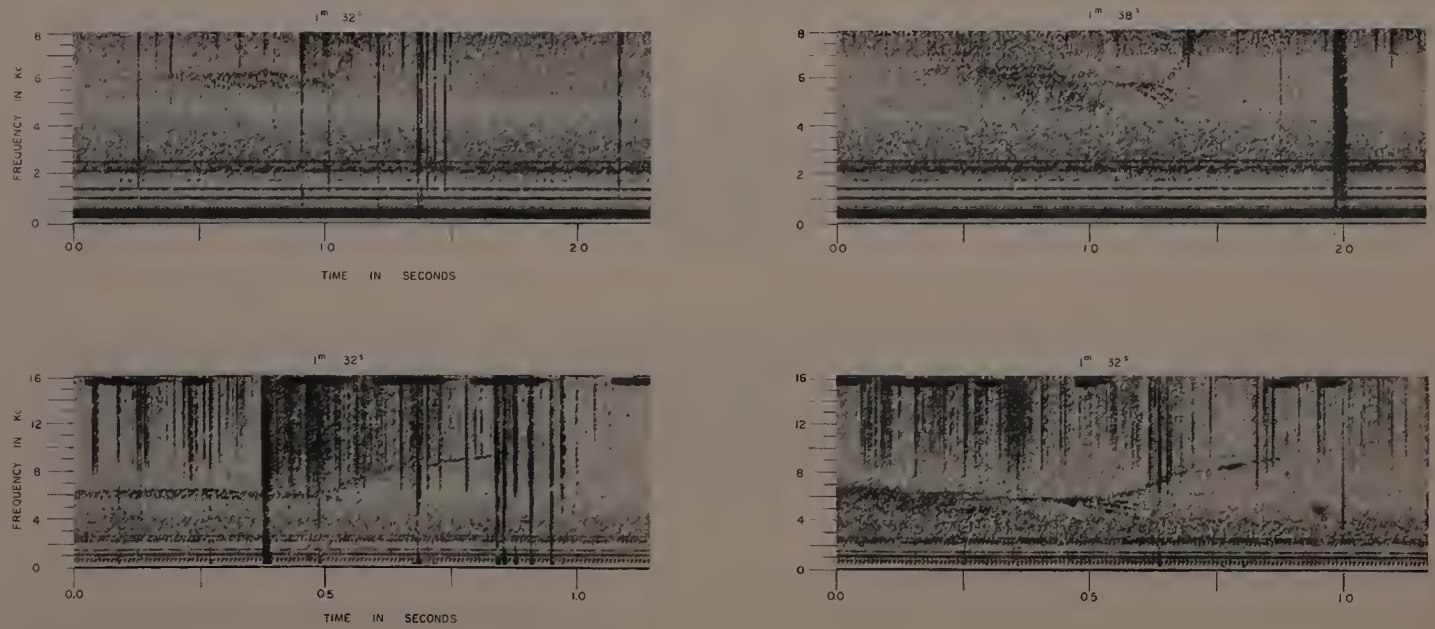


27 APRIL 1956
1740 UT



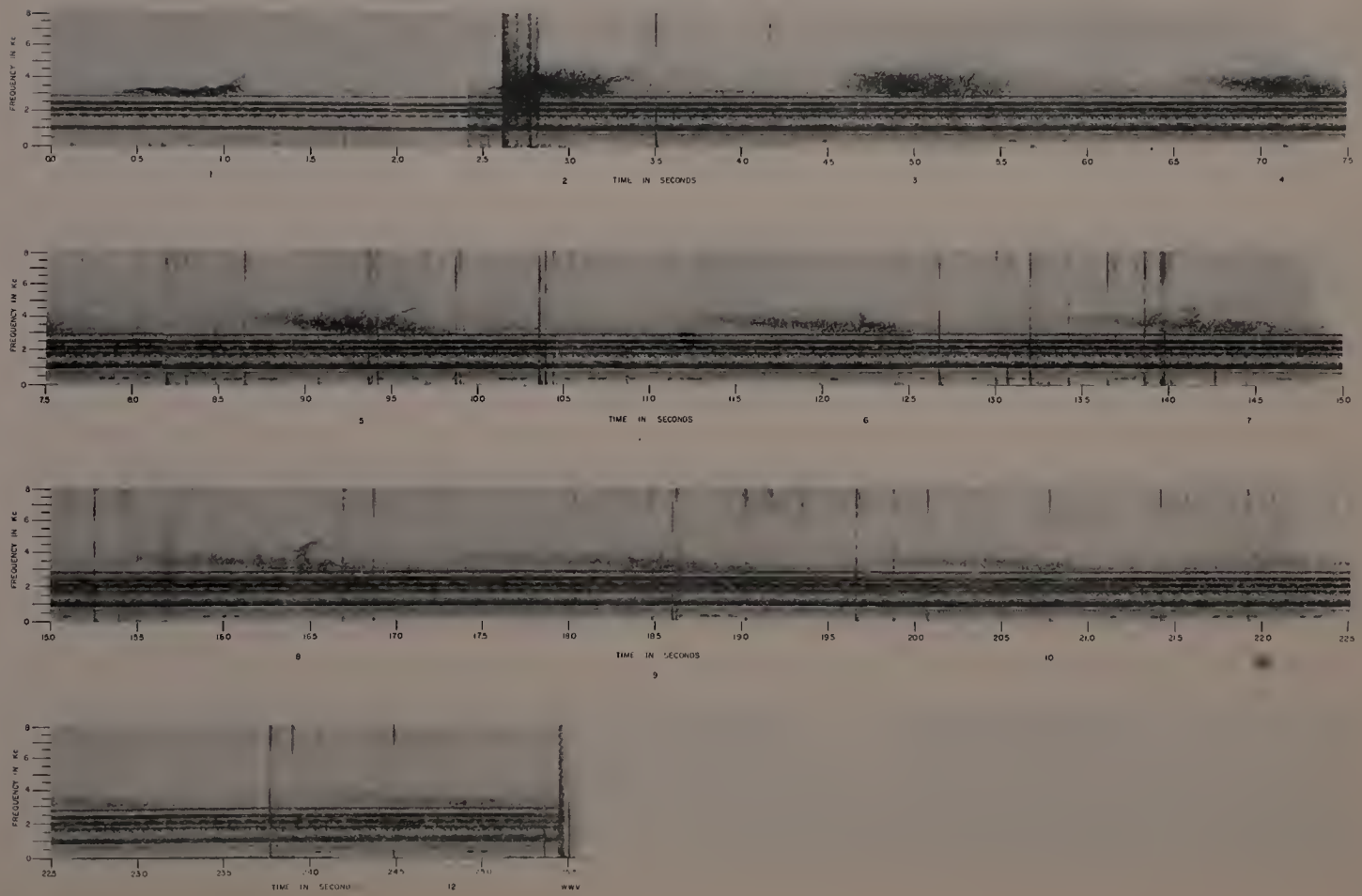
COMPLEX EVENTS

17 NOVEMBER 1956
1535 UT



STRANGE EMISSION WITH TRAIN OF ECHOES

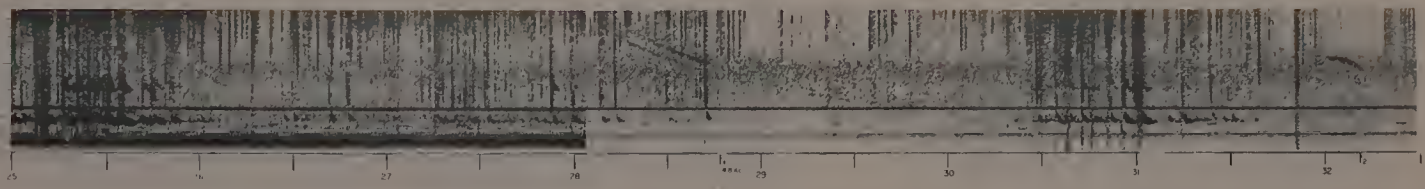
27 FEBRUARY 1956 2102.22 UT (SECOND TRAIN) BOULDER, COLORADO

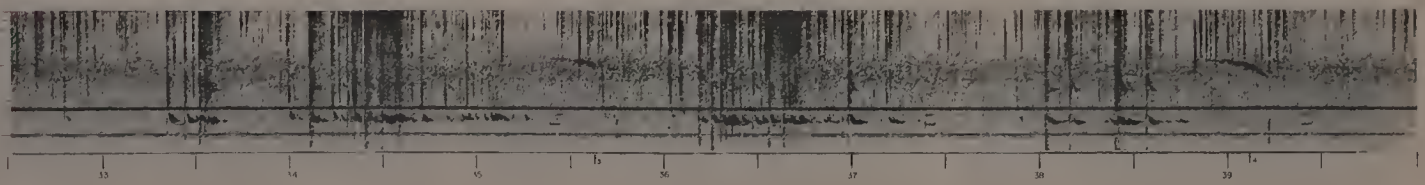


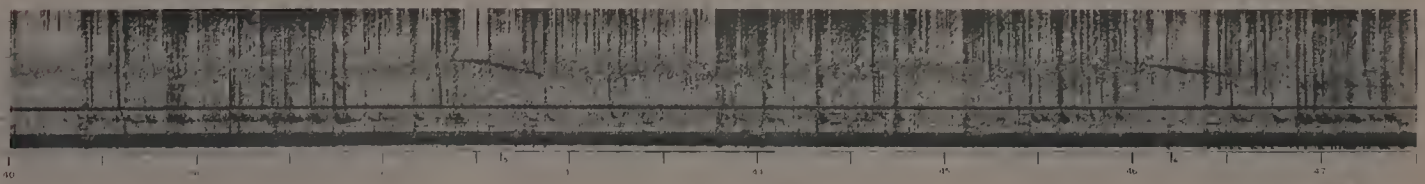
ECHOING VLF EMISSION

27 NOVEMBER 1957

0335 UT

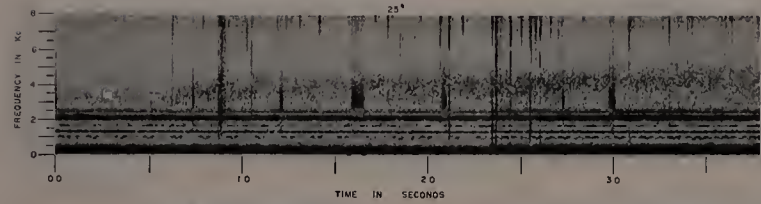




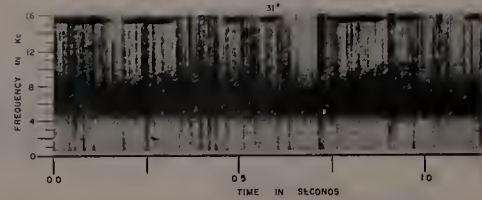


HISS

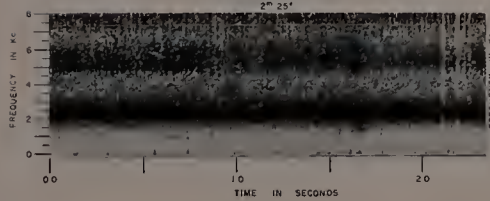
28 OCTOBER 1956
1535 UT



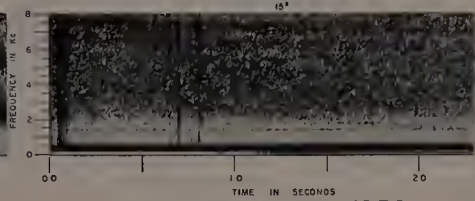
2 MARCH 1957
0635 UT



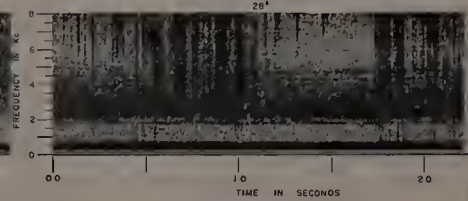
16 MAY 1956
2035 UT



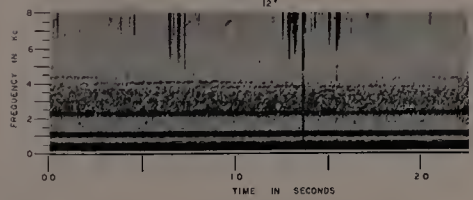
22 JANUARY 1957
0335 UT



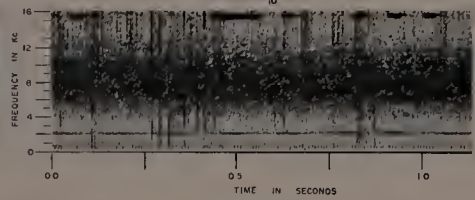
20 FEBRUARY 1957
0435 UT



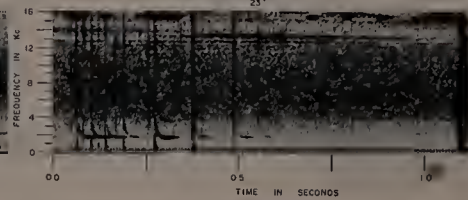
10 JANUARY 1957
2235 UT



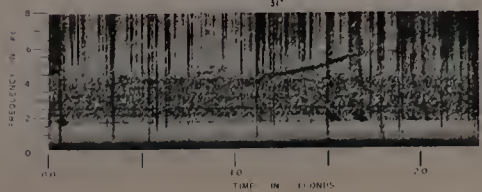
12 NOVEMBER 1956
1335 UT



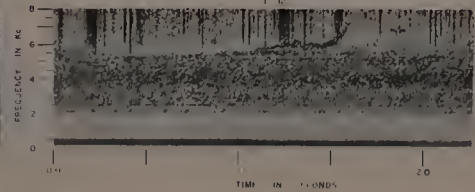
12 NOVEMBER 1956
0235 UT



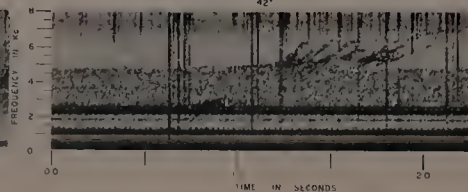
1 FEBRUARY 1957
0935 UT



13 FEBRUARY 1957
2335 UT

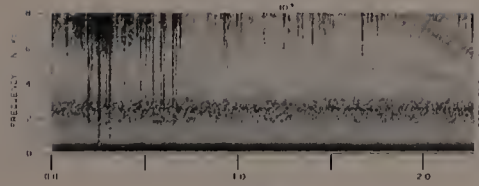


28 DECEMBER 1956
2035 UT

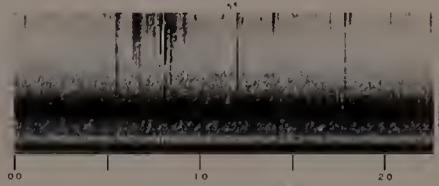


HISS

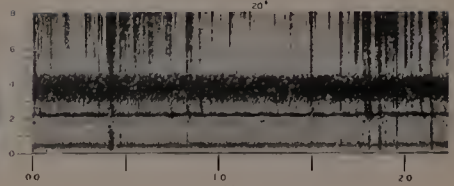
22 JANUARY 1957
2255 UT



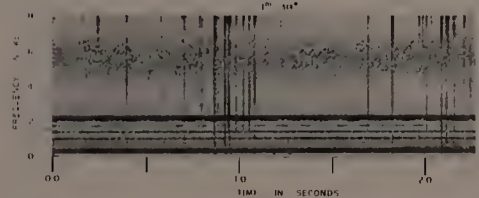
27 DECEMBER 1956
2135 UT



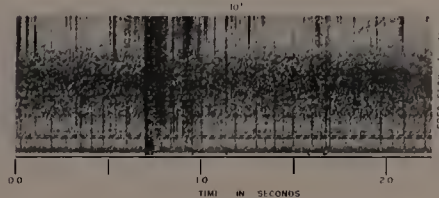
27 MARCH 1957
0135 UT



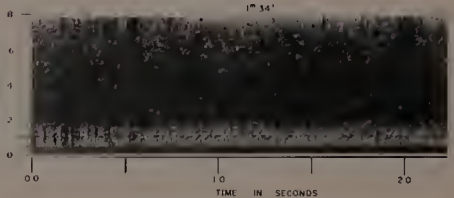
10 NOVEMBER 1956
1635 UT



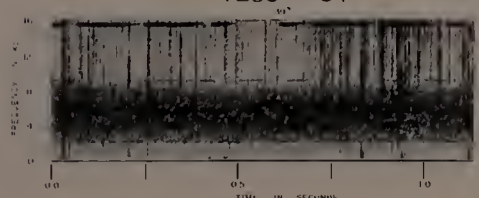
15 NOVEMBER 1956
1935 UT



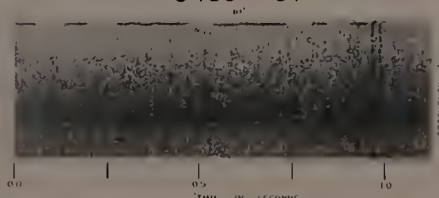
12 NOVEMBER 1956
0135 UT



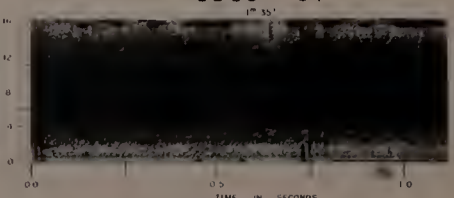
17 NOVEMBER 1956
1235 UT



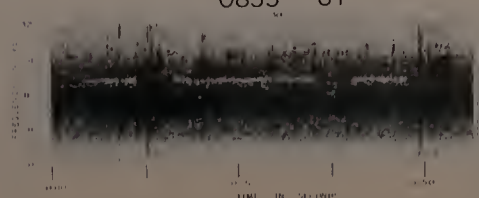
13 OCTOBER 1956
0435 UT



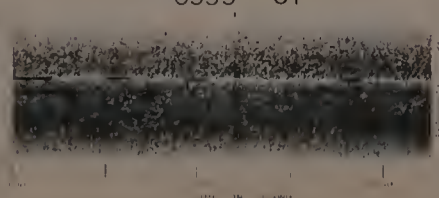
12 NOVEMBER 1956
0335 UT



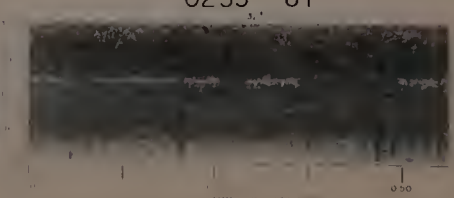
2 MARCH 1957
0835 UT



2 APRIL 1957
0535 UT

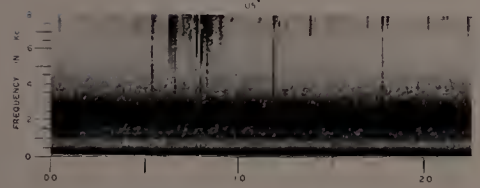


7 APRIL 1957
0235 UT



TRANSITION FROM HISS TO DETAILED STRUCTURE

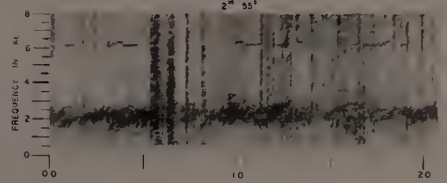
27 DECEMBER 1956
2135 UT



25 MAY 1956
1235 UT

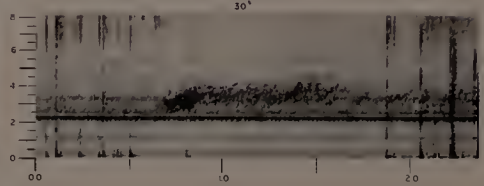
25 MAY 1956
1135 UT

26 JULY 1956
1235 UT

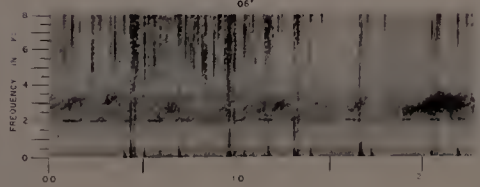


24 JUNE 1956
1535 UT

25 MAY 1956
1535 UT

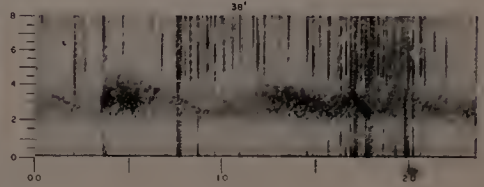


24 JUNE 1956
1535 UT



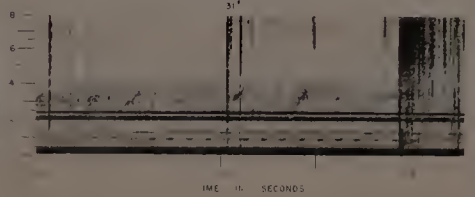
24 JUNE 1956
1635 UT

24 JUNE 1956
1635 UT

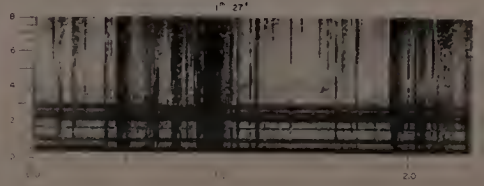


21 OCTOBER 1956
1335 UT

21 NOVEMBER 1956
1435 UT



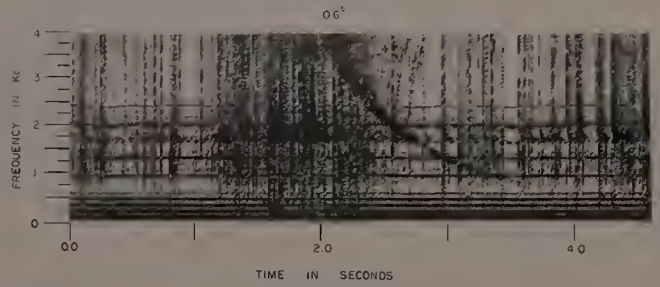
21 SEPTEMBER 1956
1435 UT

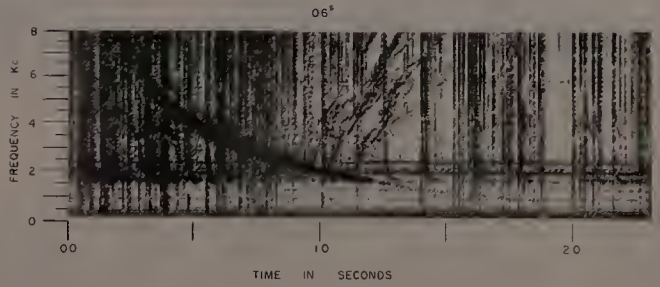


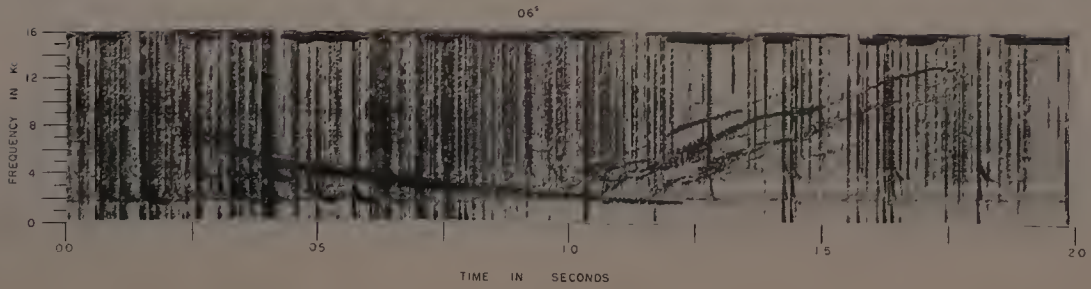
SECTION IV

INTERACTIONS BETWEEN WHISTLERS AND VLF EMISSIONS

20 NOVEMBER 1956
0036 UT

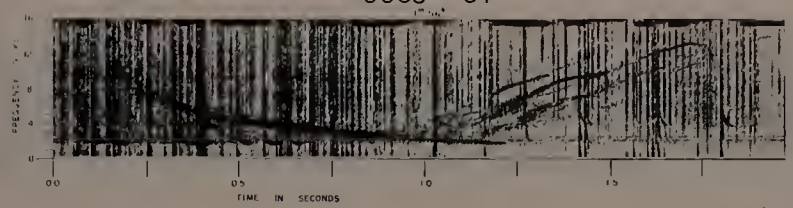




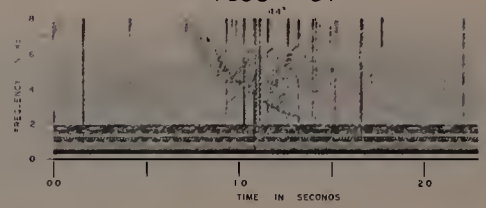


WHISTLER FOLLOWED BY VLF EMISSION

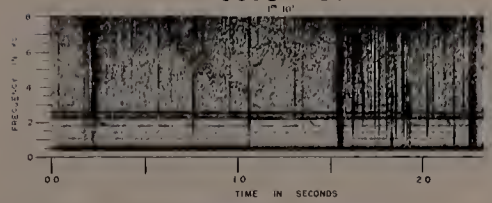
20 NOVEMBER 1956
0035 UT



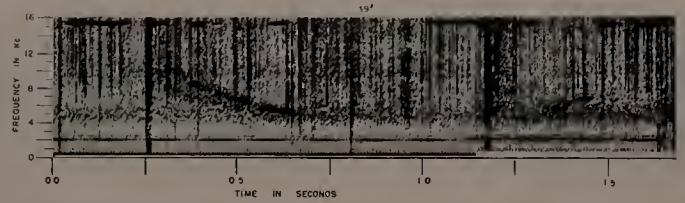
10 APRIL 1957
1635 UT



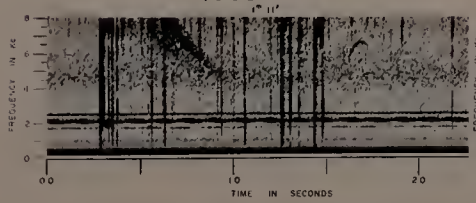
23 JANUARY 1957
0935 UT



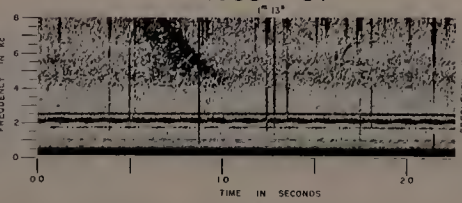
2 JANUARY 1957
1335 UT



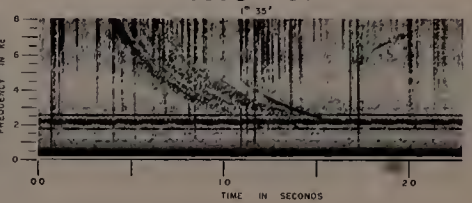
2 JANUARY 1957
1335 UT



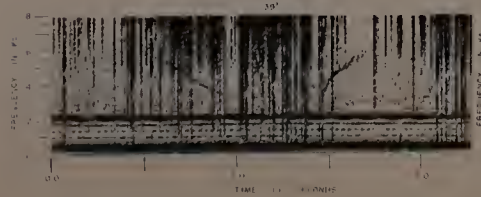
2 JANUARY 1957
1335 UT



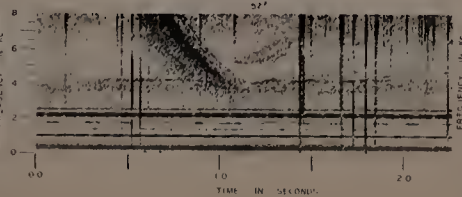
9 FEBRUARY 1957
0535 UT



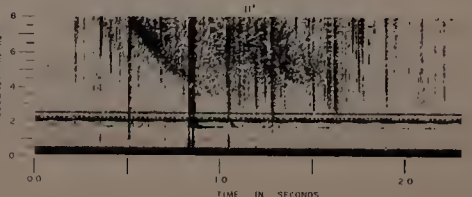
13 MARCH 1957
1435 UT



24 NOVEMBER 1956
1435 UT



2 JANUARY 1957
0535 UT

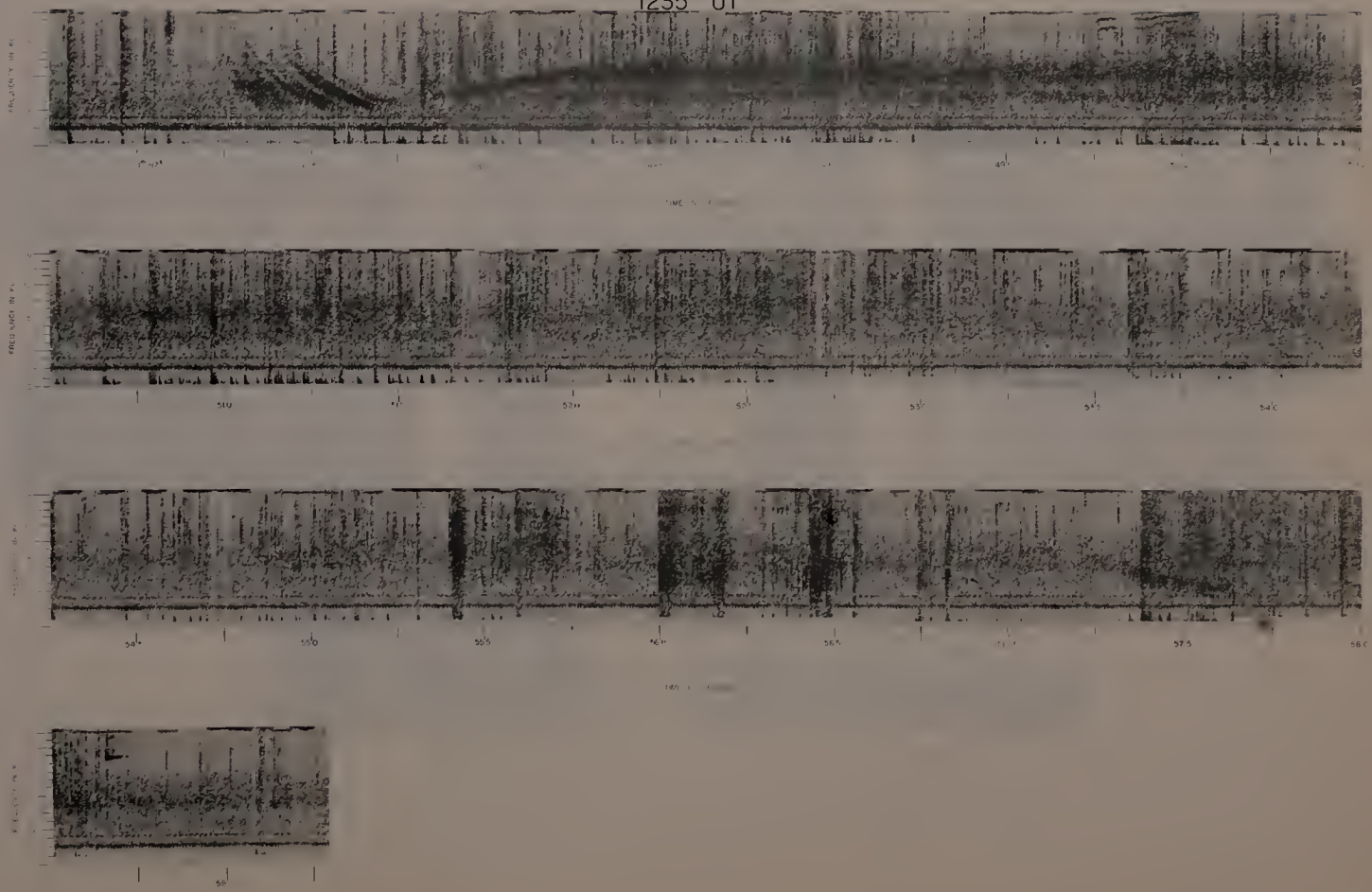


HISS OF COMPLEX STRUCTURE TRIGGERED BY A WHISTLER

(whistler type short MP, D≃40)

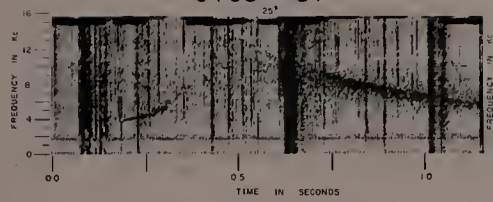
18 MAY 1956

1235 UT

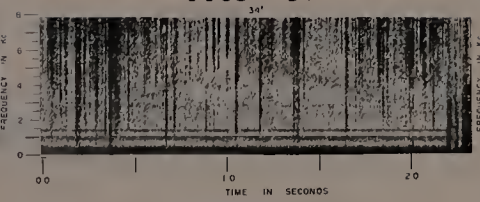


INTERACTIONS

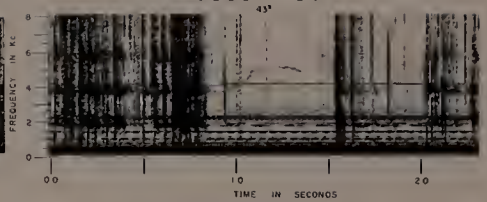
13 NOVEMBER 1956
0135 UT



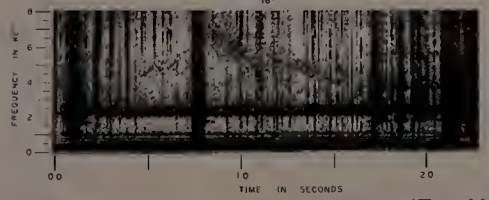
22 MARCH 1957
0035 UT



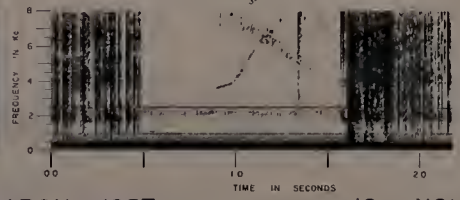
24 OCTOBER 1956
1035 UT



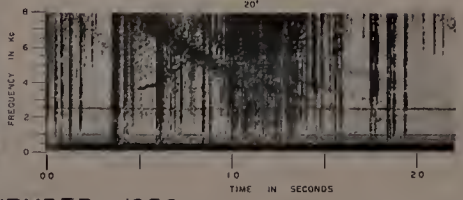
21 OCTOBER 1956
0935 UT



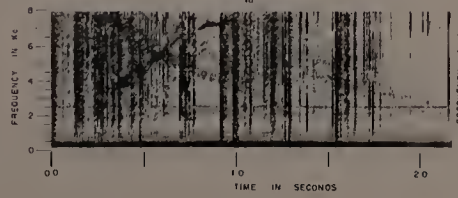
17 MARCH 1957
1035 UT



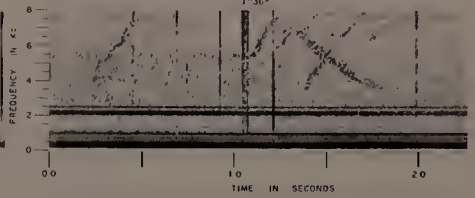
17 MARCH 1957
1235 UT



17 MARCH 1957
1135 UT



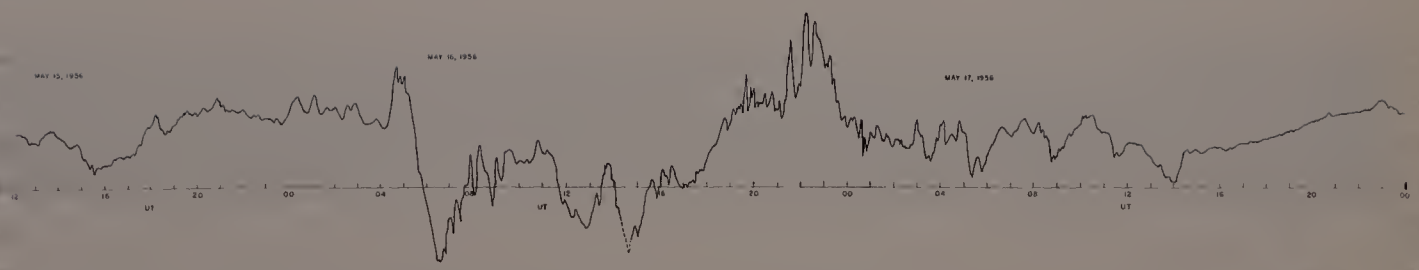
10 NOVEMBER 1956
1435 UT



SECTION V

PERIODS OF SPECIAL INTEREST SELECTED BY THEIR VLF ACTIVITY

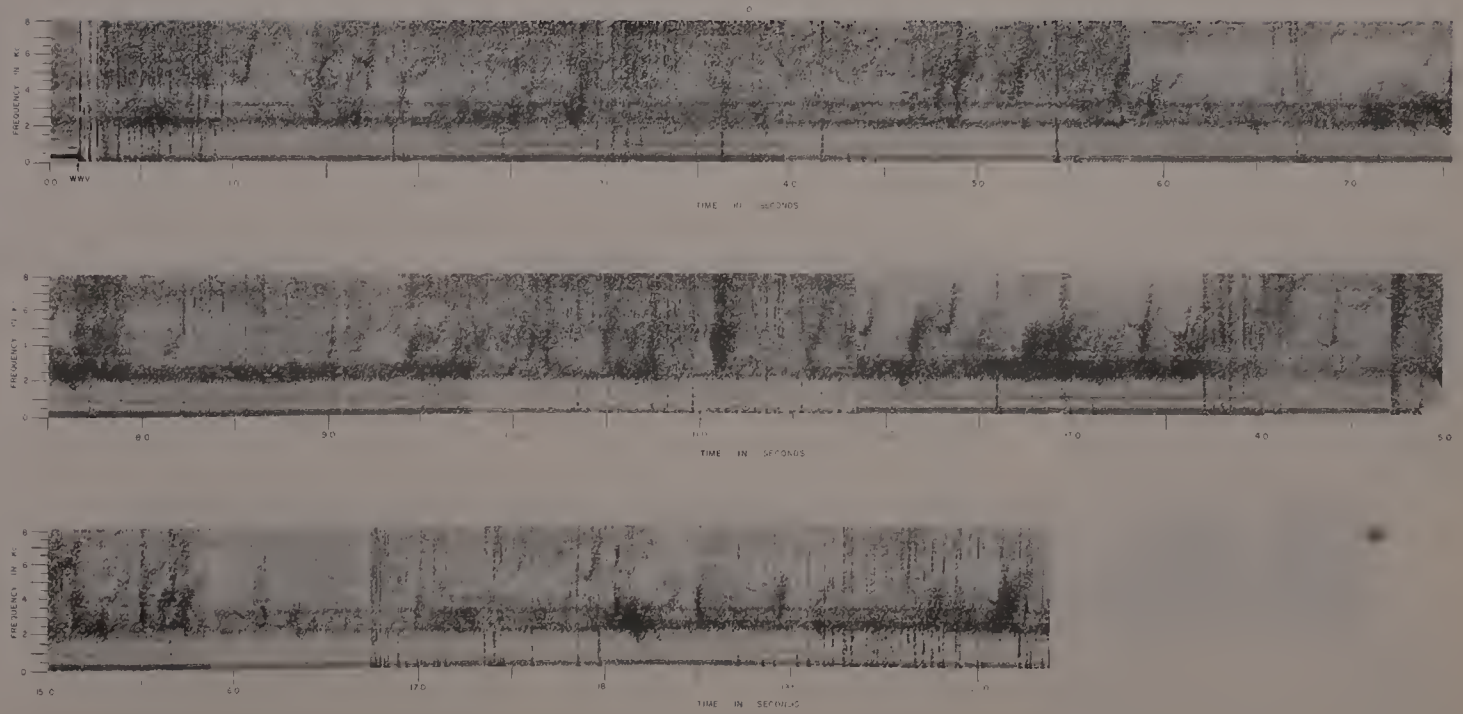
MAGNETOGRAM FROM CHELTENHAM OBSERVATORY
HORIZONTAL COMPONENT



UNUSUAL VLF ACTIVITY

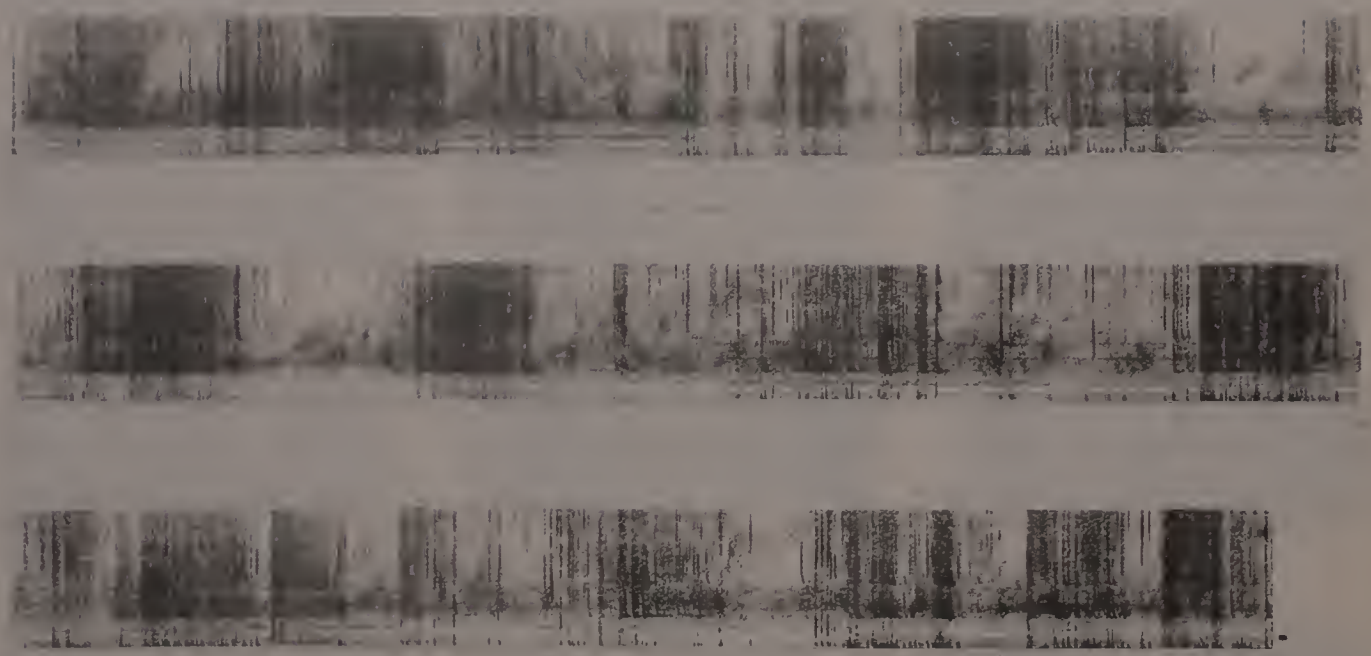
ASSOCIATED WITH A STRONG MAGNETIC DISTURBANCE

16 MAY 1956
1335 UT



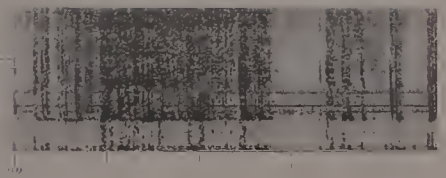
16 MAY 1956

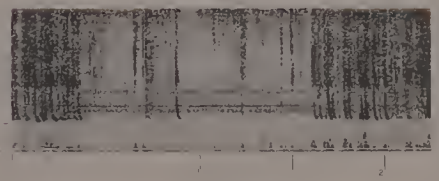
01[illegible] UT

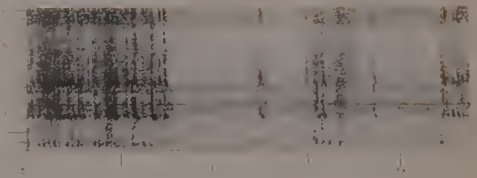


16 MAY 1956

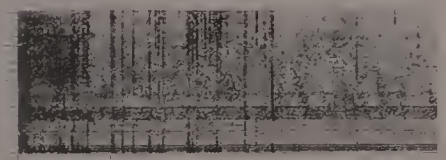
0635 UT

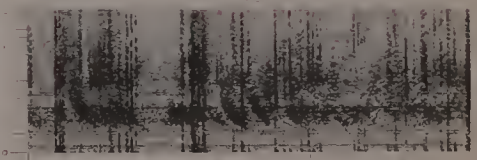




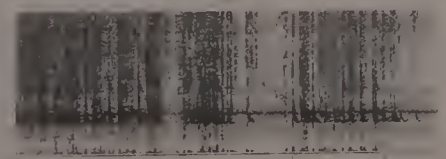


0735 UT





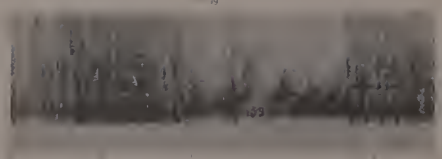
0835 UT



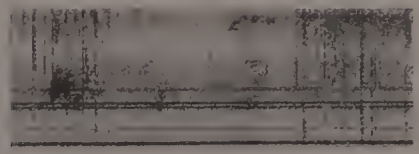
0935 UT

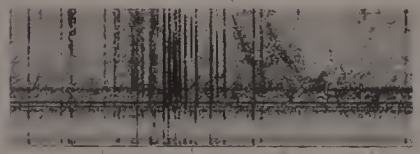
16 MAY 1956

1035 UT

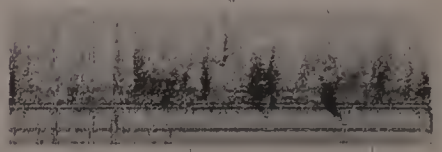


1155 UT

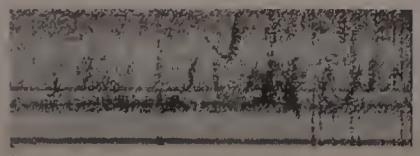


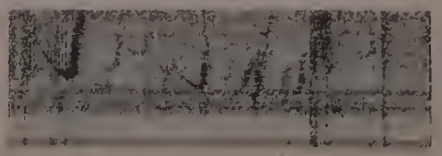


1235 UT



1355 UT

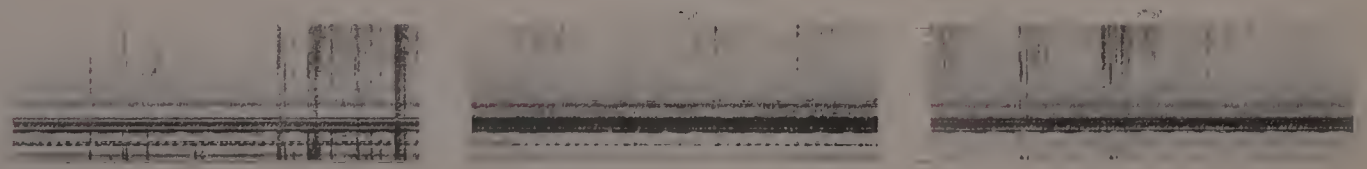




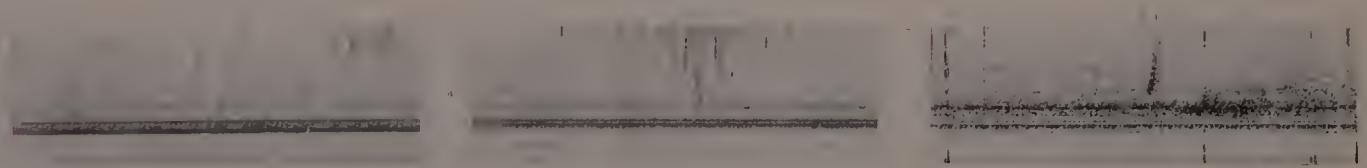
16 MAY 1956

1435 UT

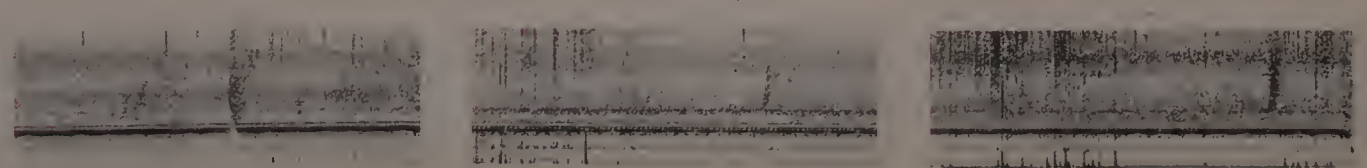
1535 UT



1635 UT

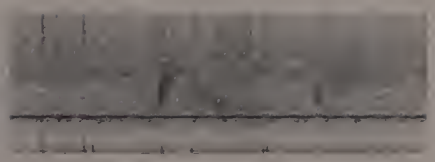


1735 UT



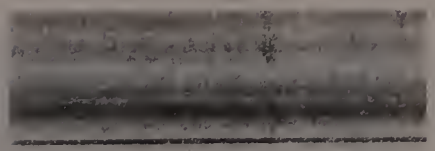
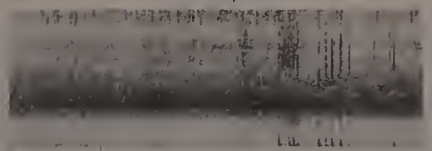
16 MAY 1956

1835 UT

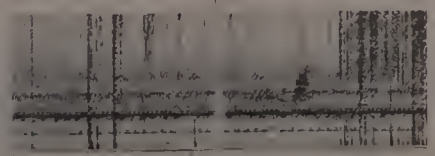
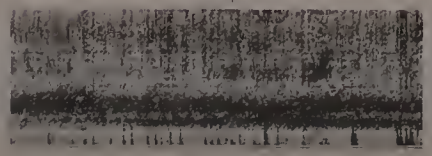


1935 UT

2035 UT

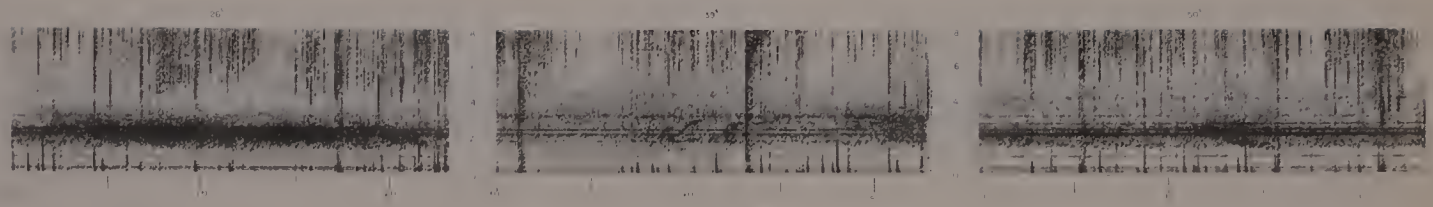



2135 UT

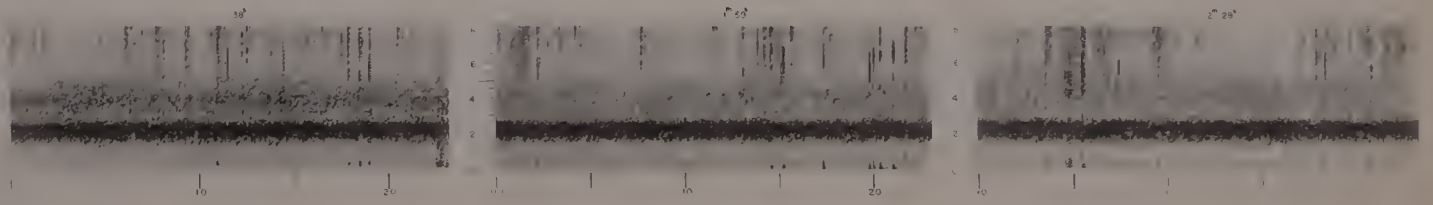



16 MAY 1956

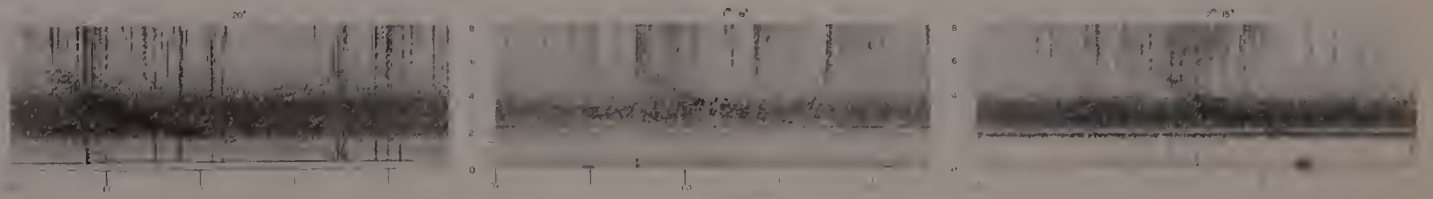
2235 UT



2335 UT



0035 UT

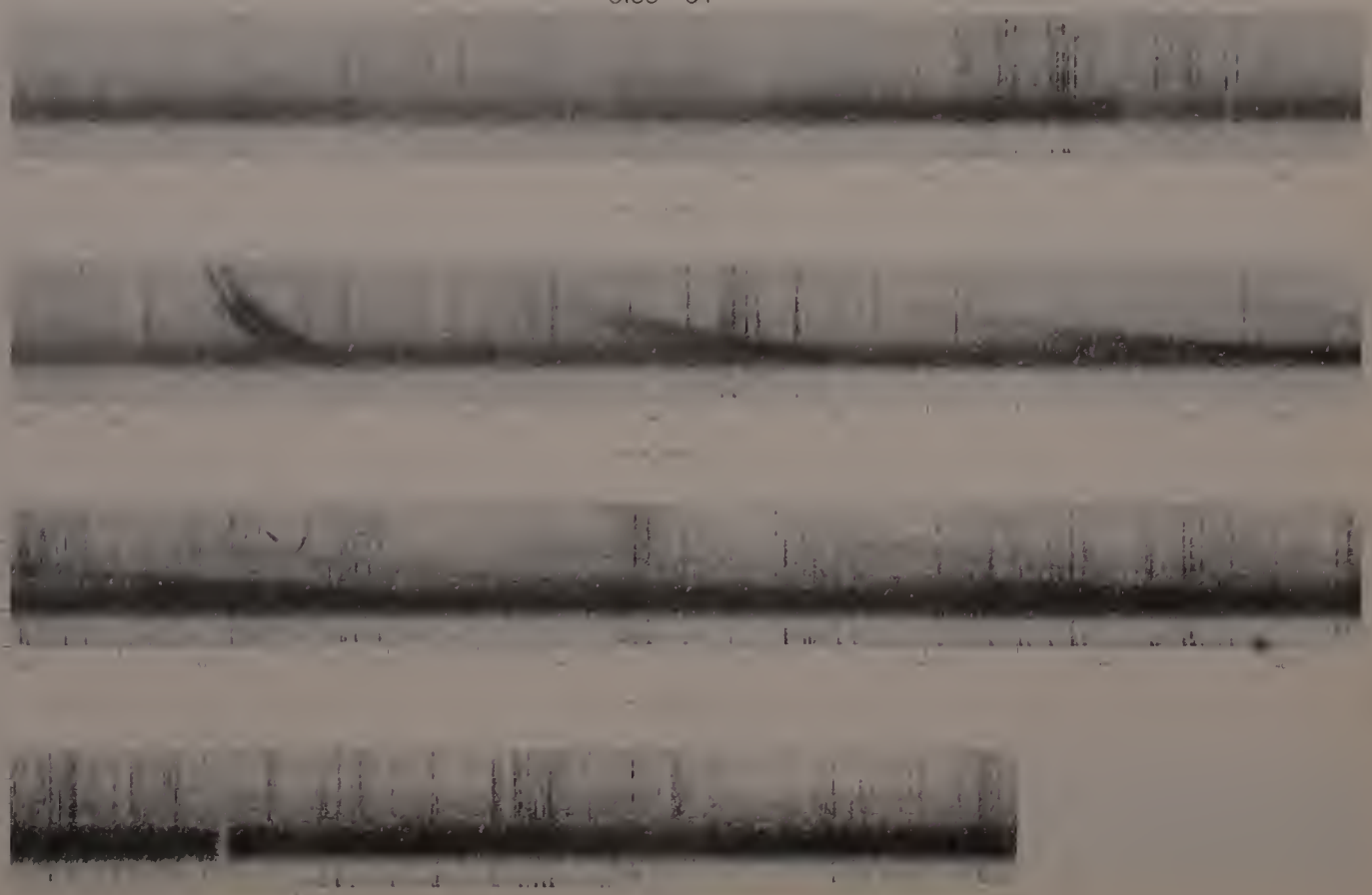


0135 UT

HISS IN CONJUNCTION WITH A WHISTLER TRAIN AND A TRIPLE ISOLATED HOOK

17 MAY 1956

0135 UT

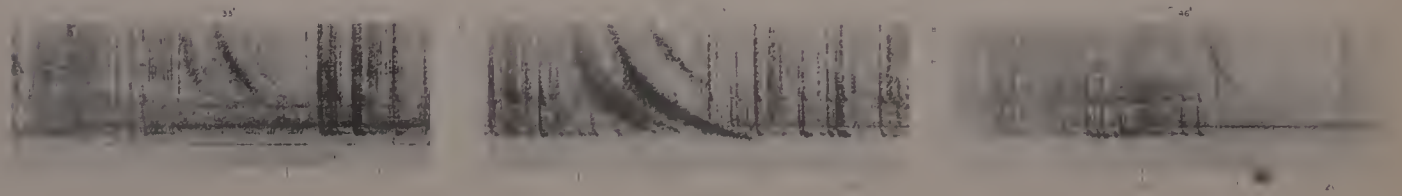


17 MAY 1956

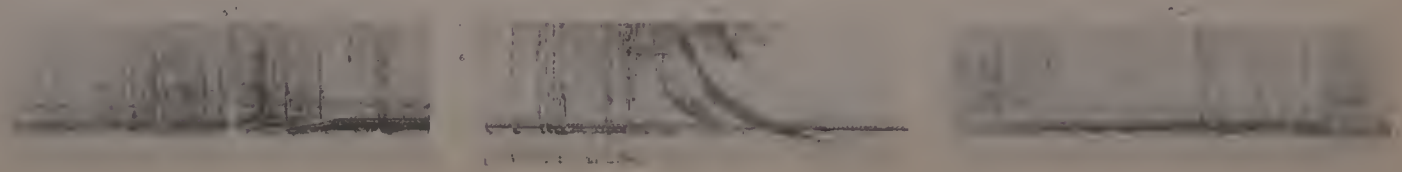
0235 UT

0335 UT

0435 UT

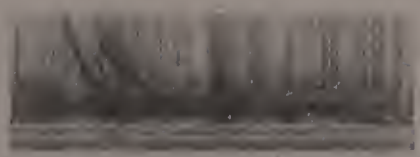
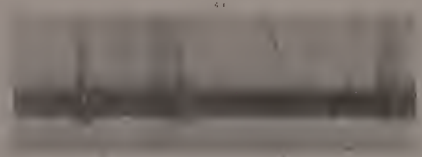


0535 UT

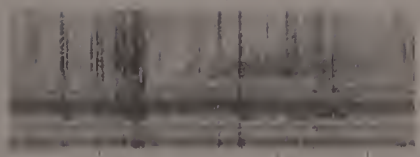
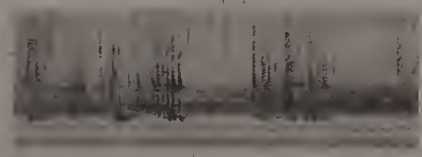
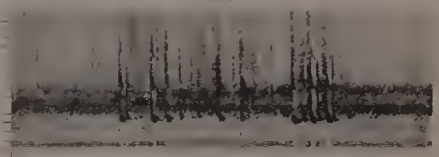


17 MAY 1956

0635 UT

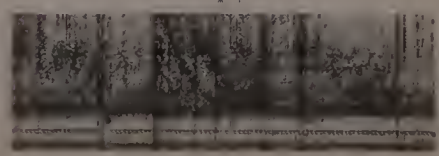



0735 UT

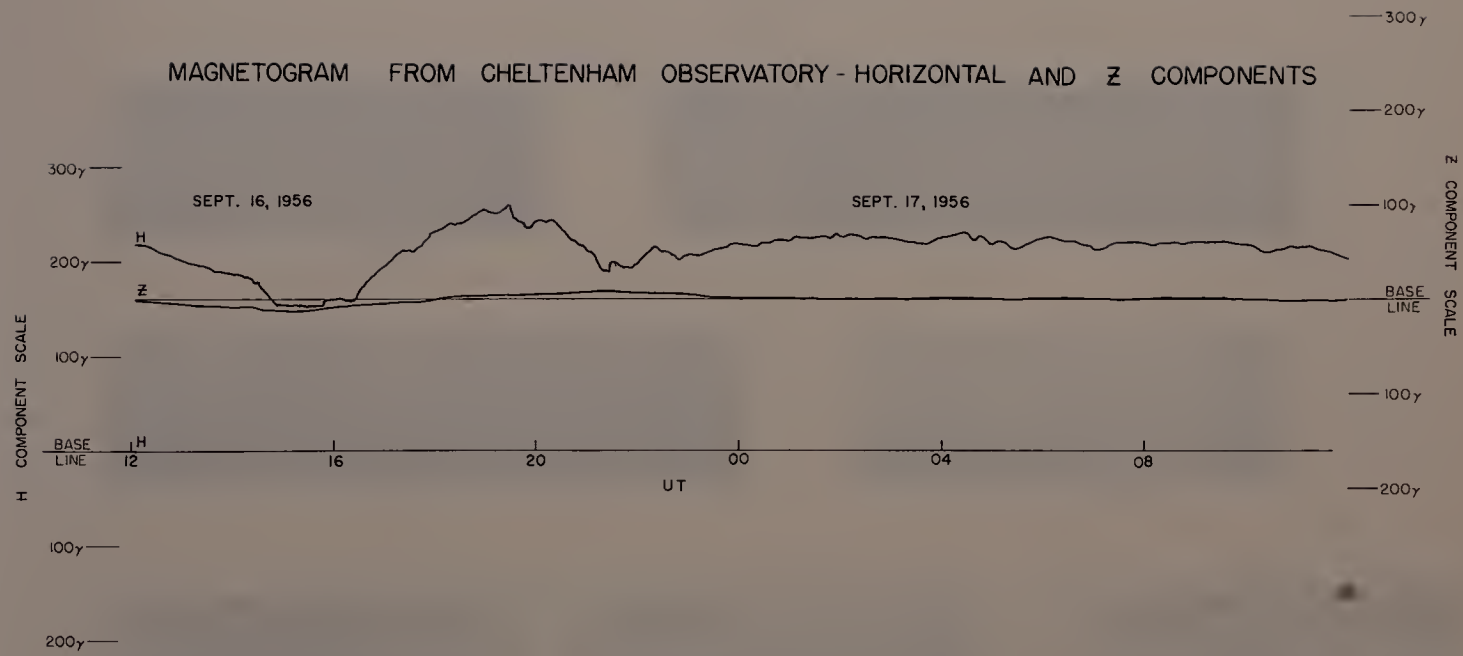




0835 UT

0935 UT



MAGNETOGRAM FROM CHELTENHAM OBSERVATORY - HORIZONTAL AND Z COMPONENTS

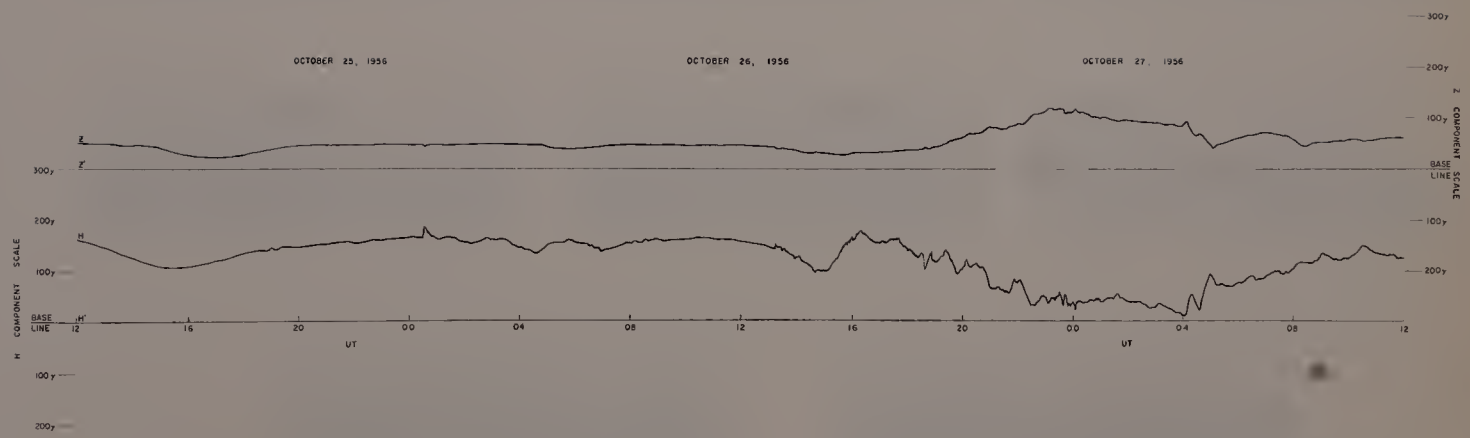


AN ISOLATED PERIOD OF VLF EMISSIONS ASSOCIATED WITH A WEAK MAGNETIC DISTURBANCE

16 SEPT 1956

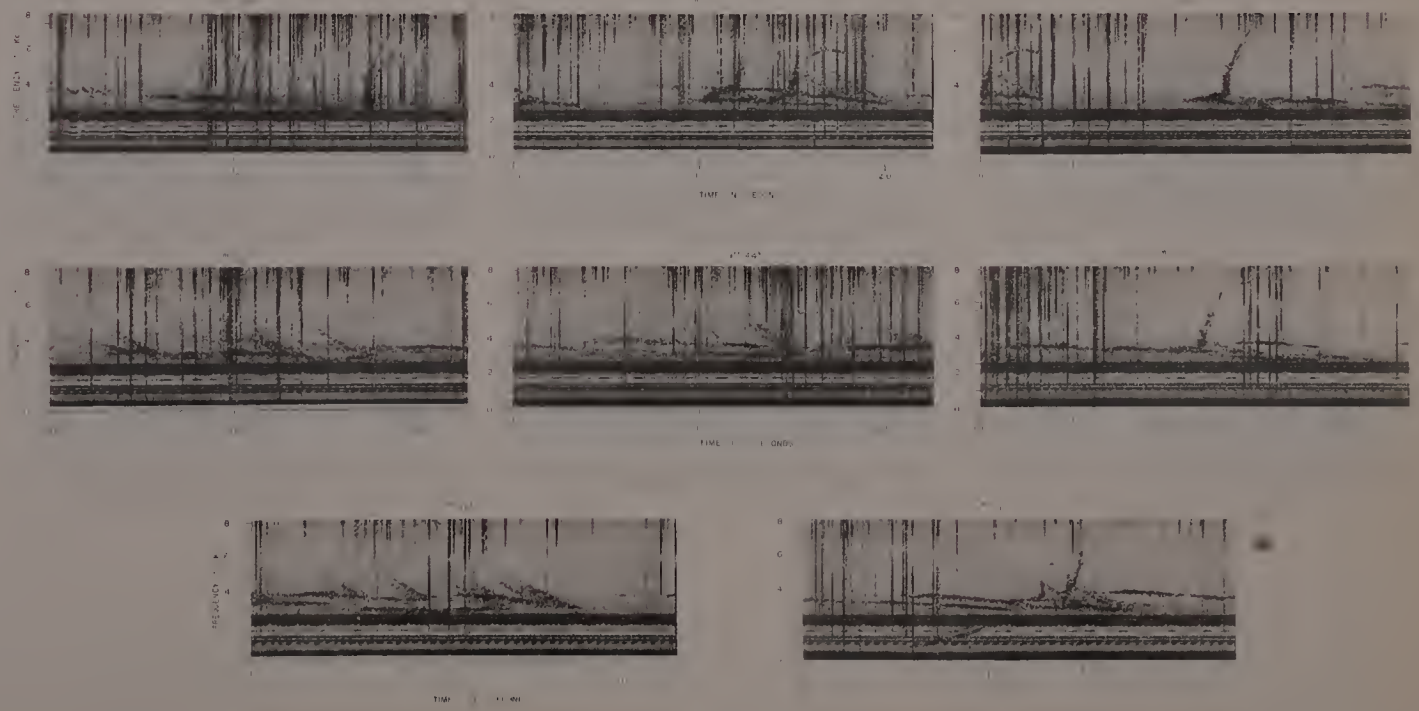
1835 UT

MAGNETOGRAM FROM FREDERICKSBURG OBSERVATORY
HORIZONTAL & Z COMPONENTS



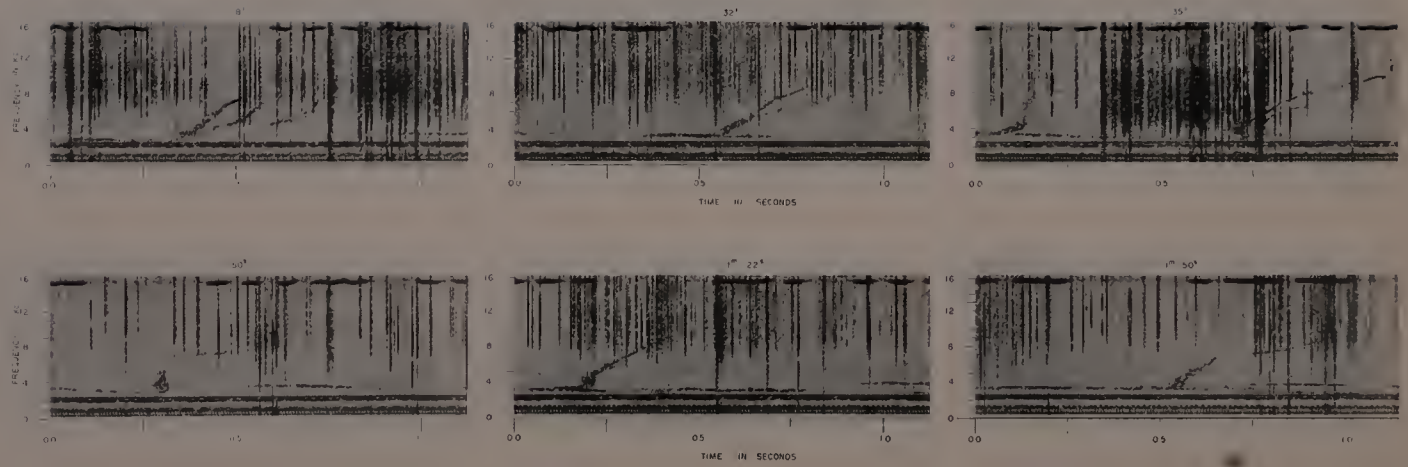
VLF EMISSIONS ASSOCIATED WITH A MODERATE MAGNETIC DISTURBANCE

26 OCTOBER 1956
2230 UT



HOOKS

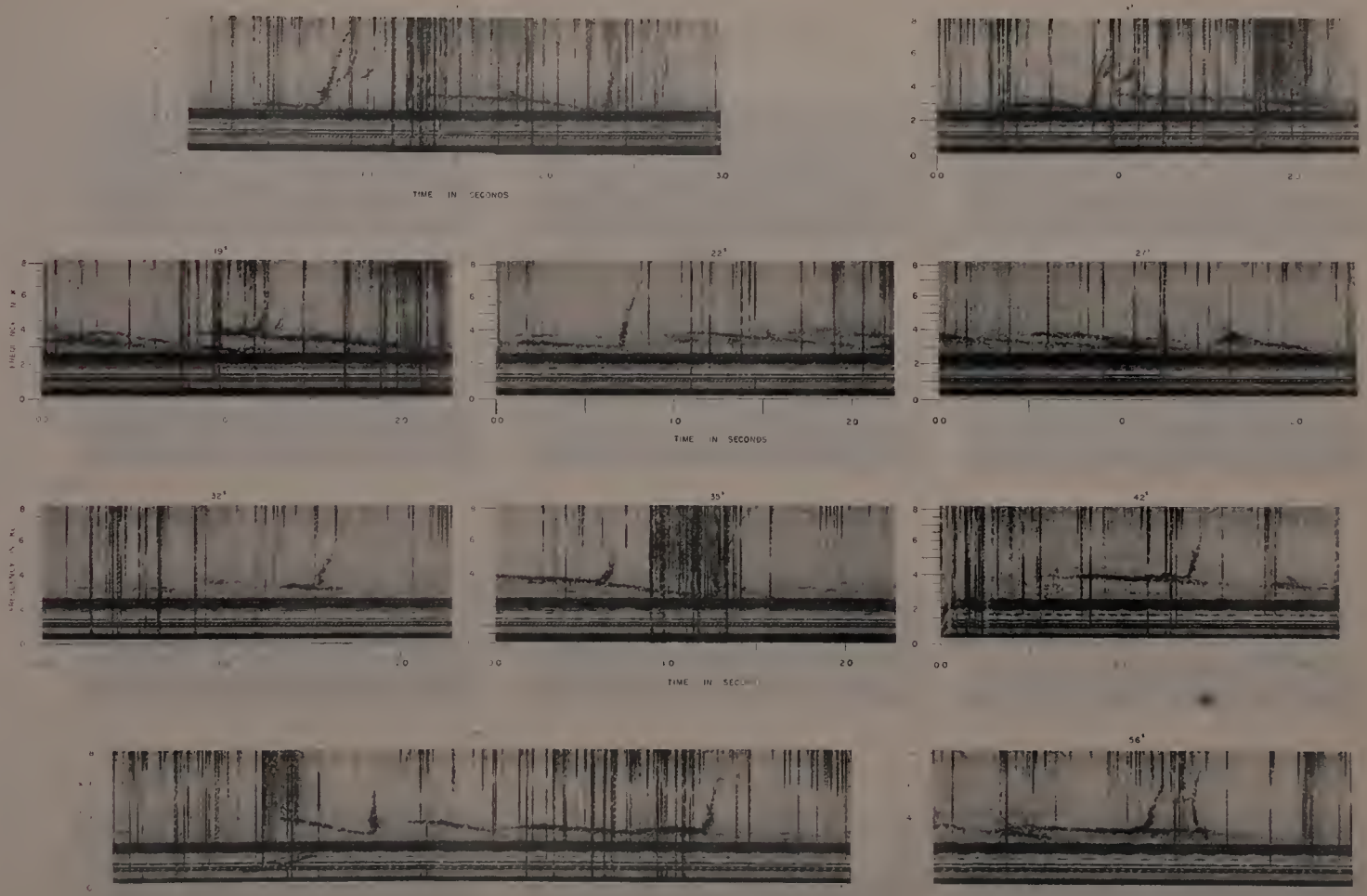
26 OCTOBER 1956
2230 UT



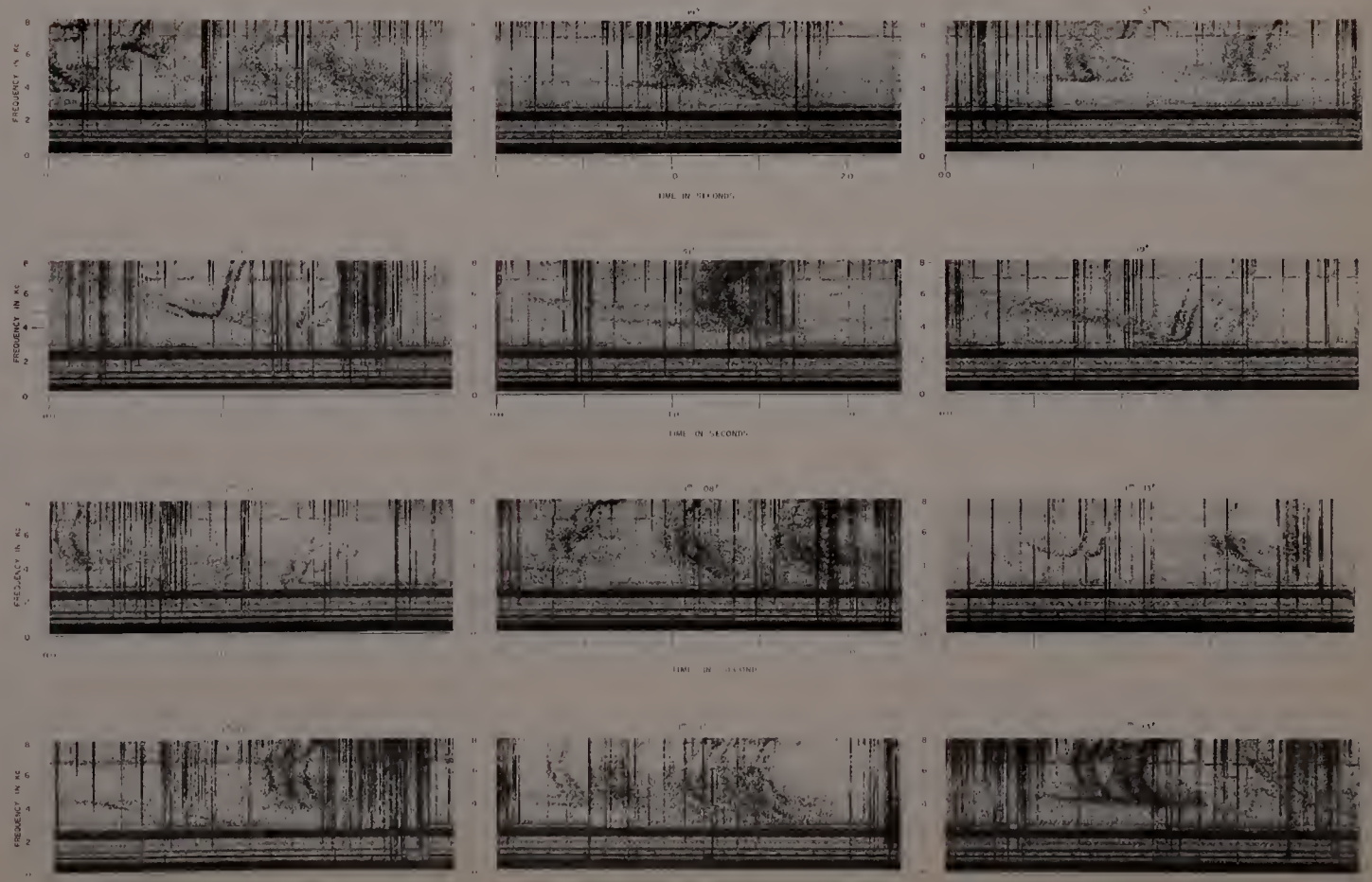
HOOKS

26 OCTOBER 1956

2230 UT

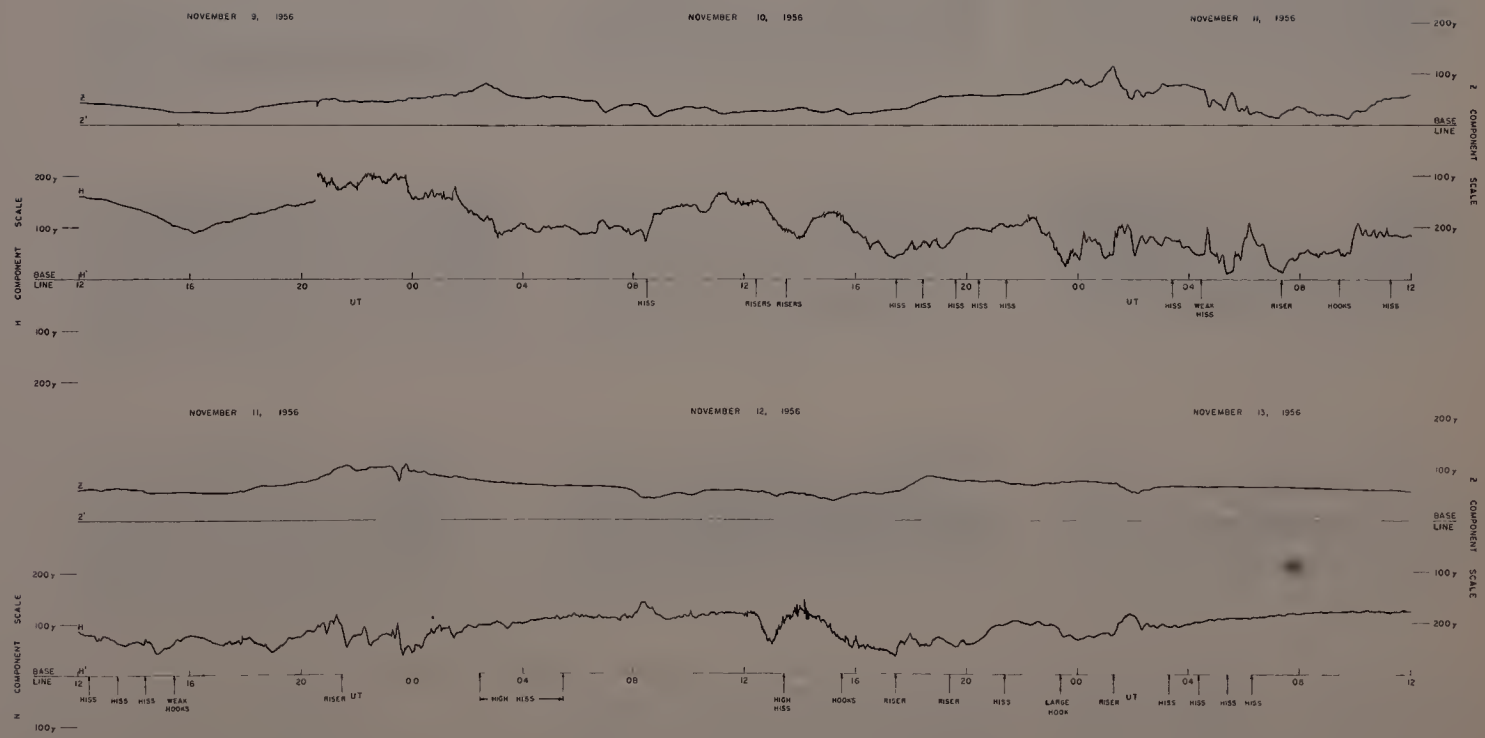


26 OCTOBER 1956
2235 UT

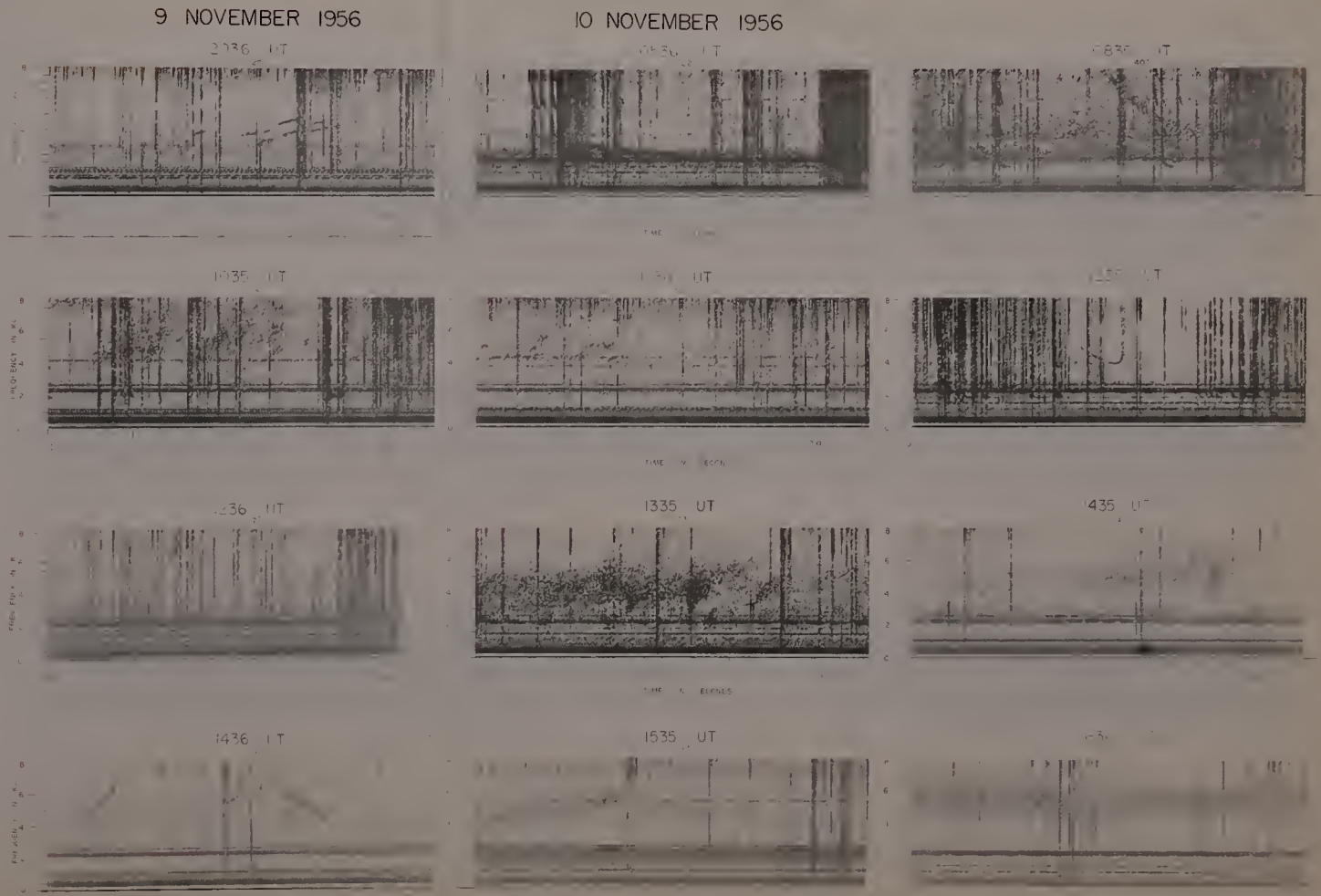


26 OCTOBER 1956
2235 UT

MAGNETOGRAM FROM FREDERICKSBURG OBSERVATORY
HORIZONTAL & Z COMPONENTS

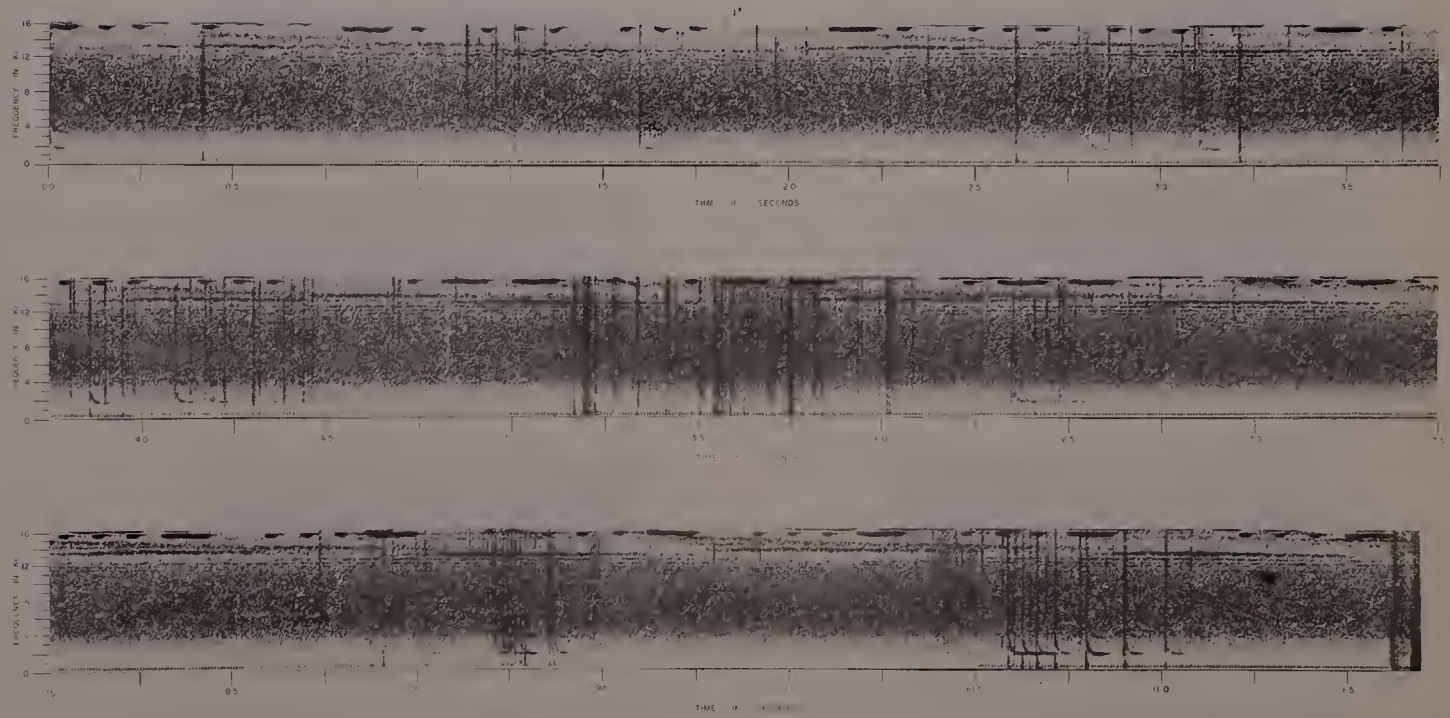


VLF ACTIVITY ASSOCIATED WITH A MODERATE MAGNETIC DISTURBANCE S. C.-9 NOVEMBER 1956 AT 20:30 U.T.



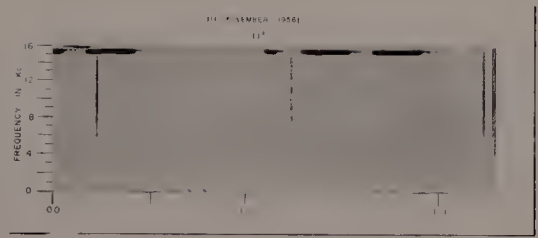
PERIOD OF STRONG HISS

12 NOVEMBER 1956
0235 UT



12 NOVEMBER 1956

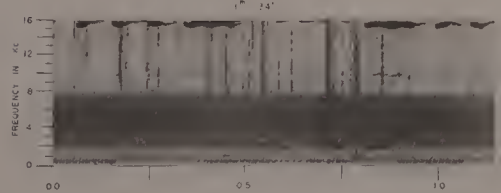
2335 UT



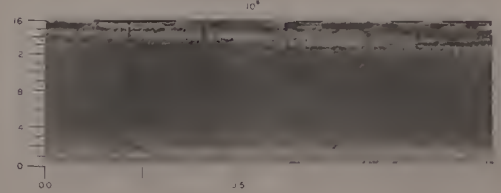
0035 UT

TIME IN SECONDS

0135 UT

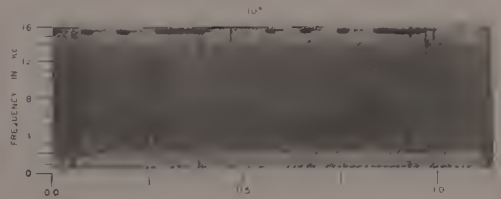


0235 UT

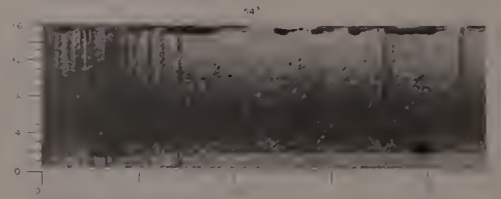


TIME IN SECONDS

0335 UT

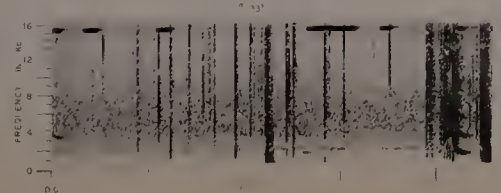


0435 UT



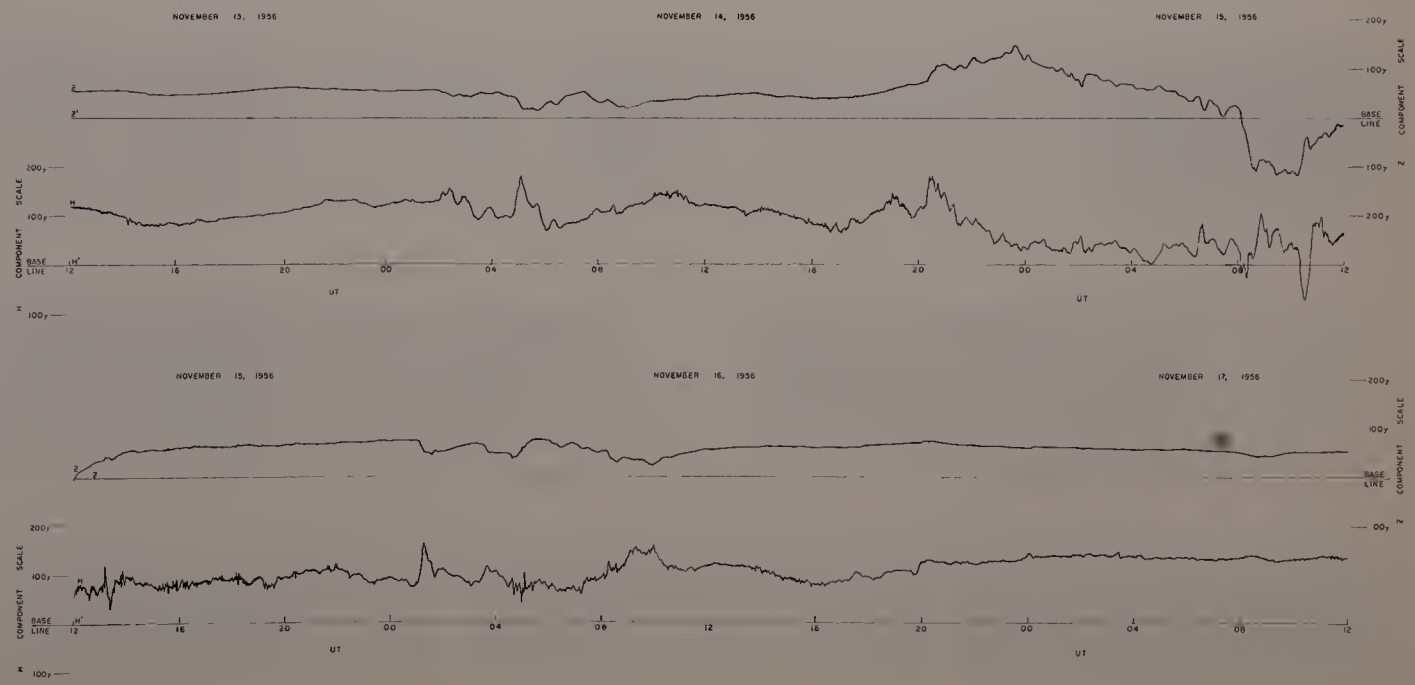
TIME IN SECONDS

0535 UT



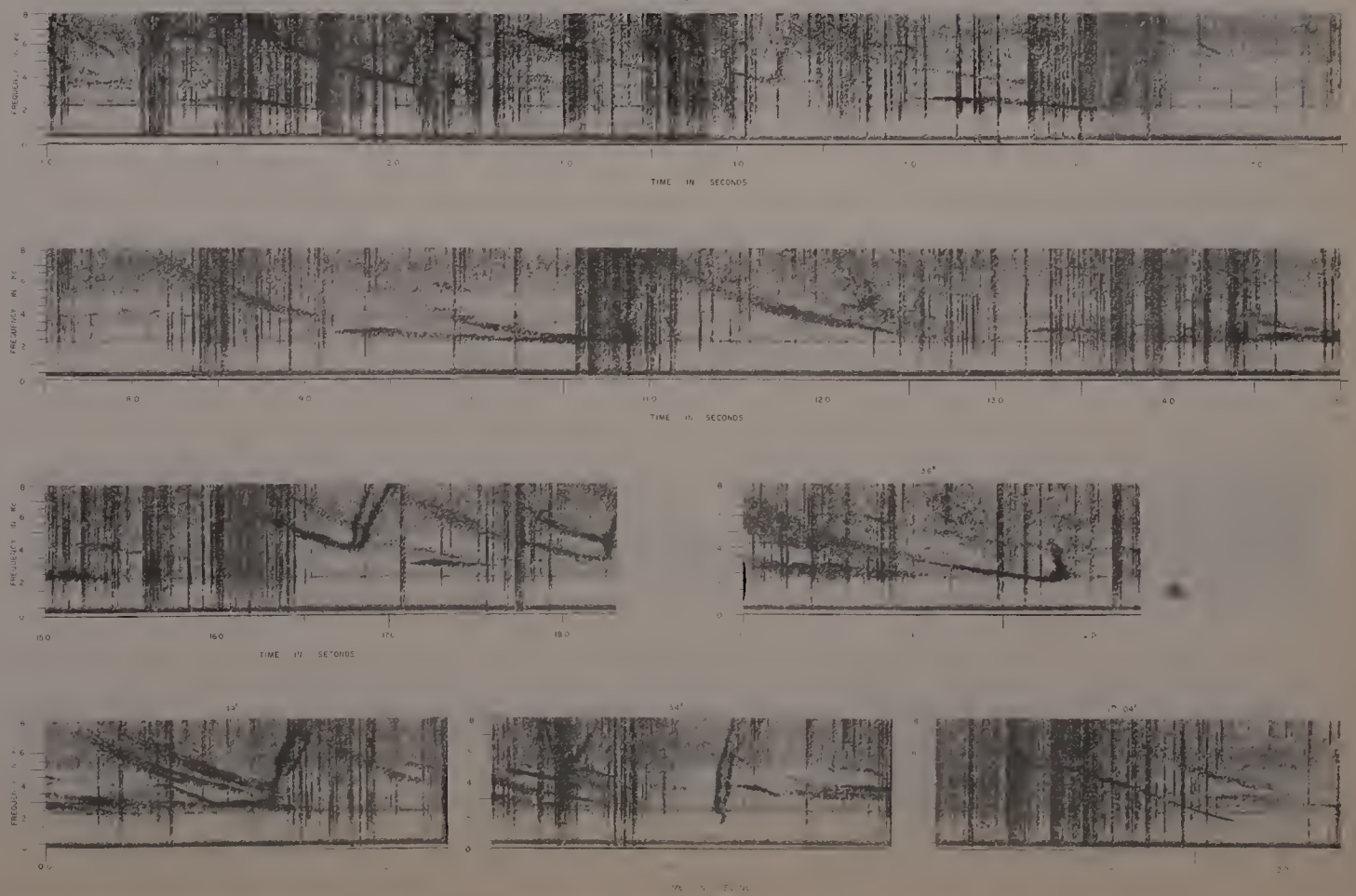
0635 UT

MAGNETOGRAM FROM FREDERICKSBURG OBSERVATORY
HORIZONTAL & Z COMPONENTS



WHISTLERS AND HOOKS

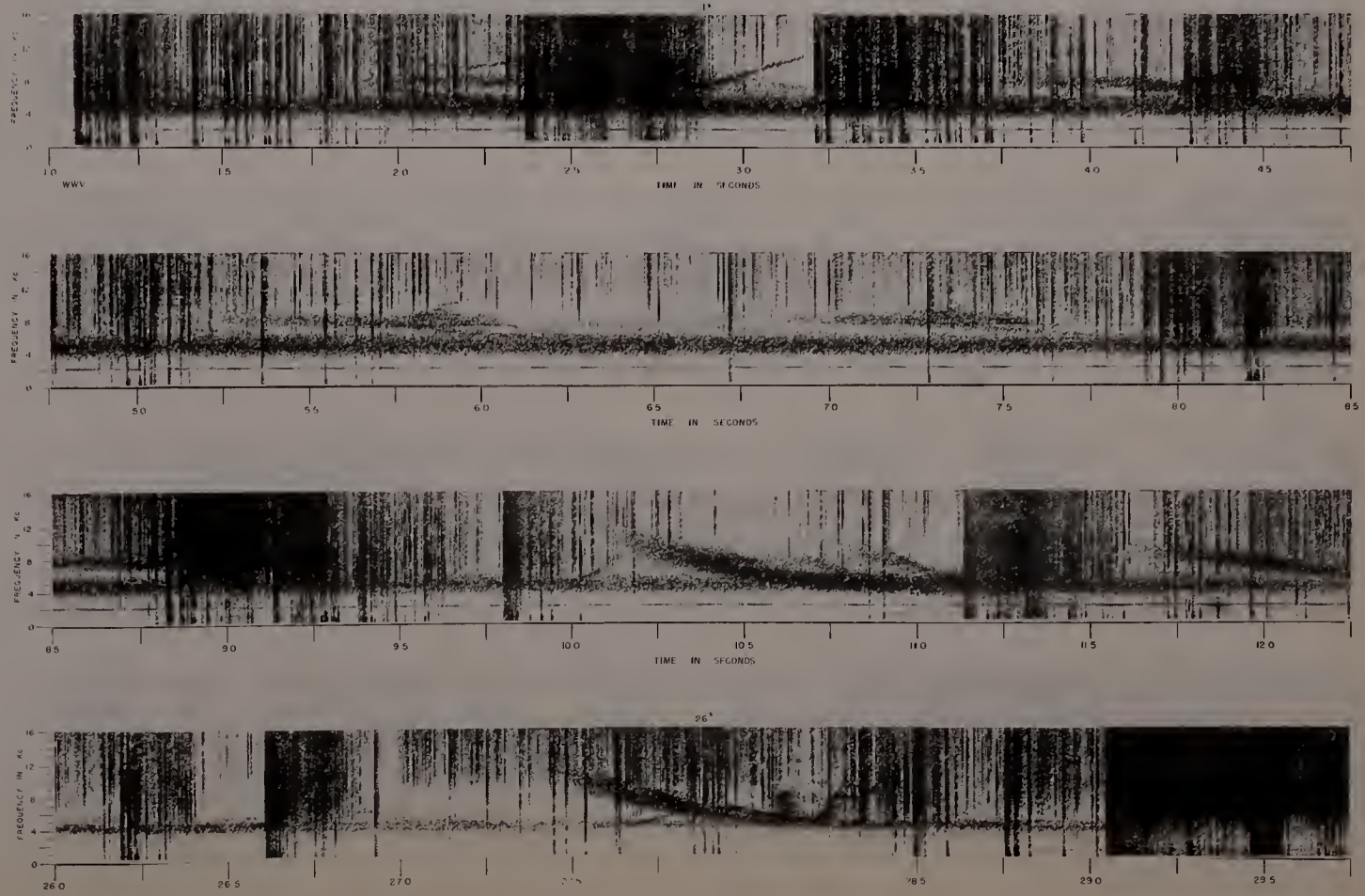
14 NOVEMBER 1956
2335 UT



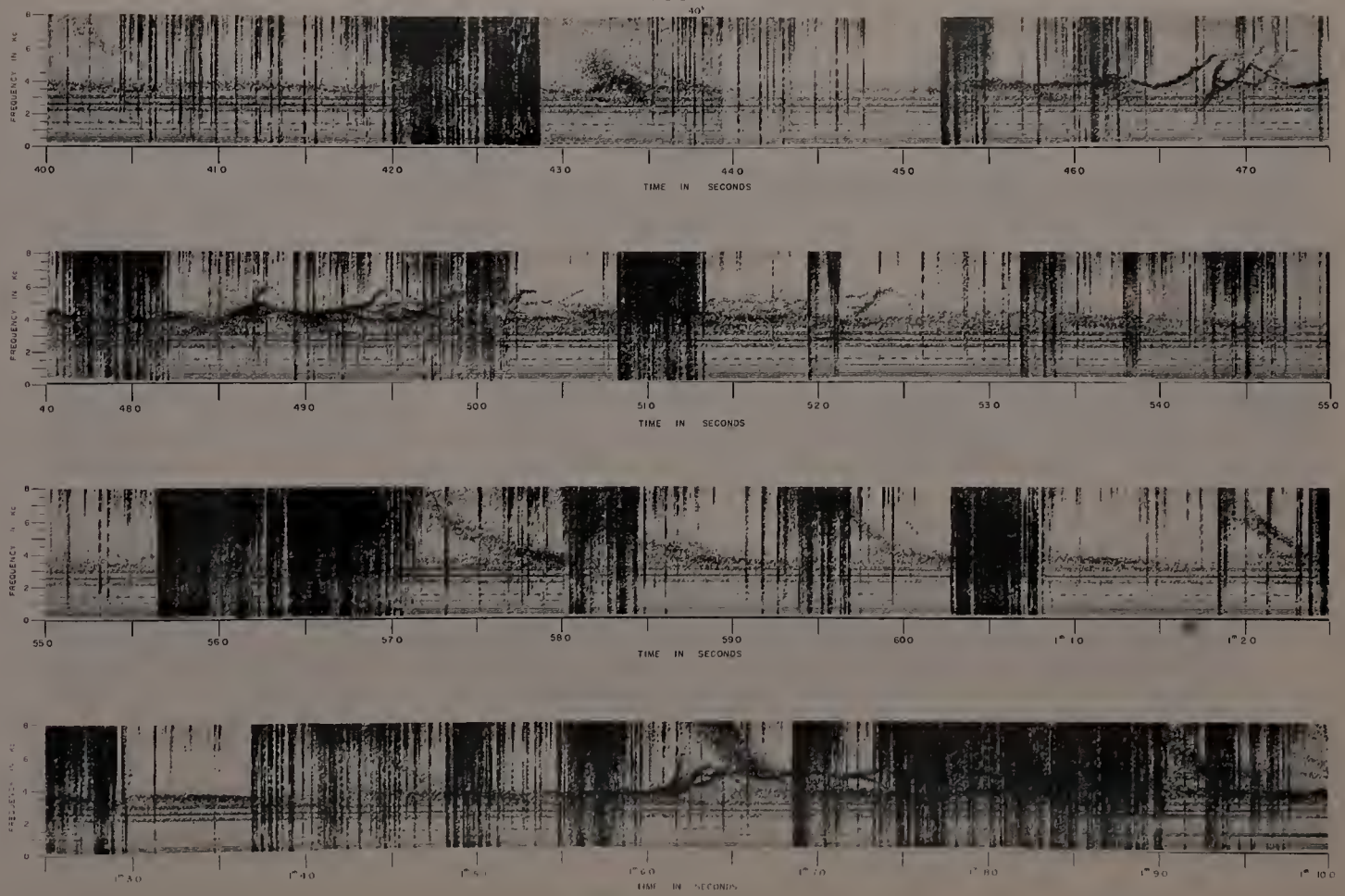
WHISTLER – VLF EMISSION INTERACTIONS ASSOCIATED WITH STRONG MAGNETIC DISTURBANCE

S. C. 30 JUNE 1957, AT 04:00 UT

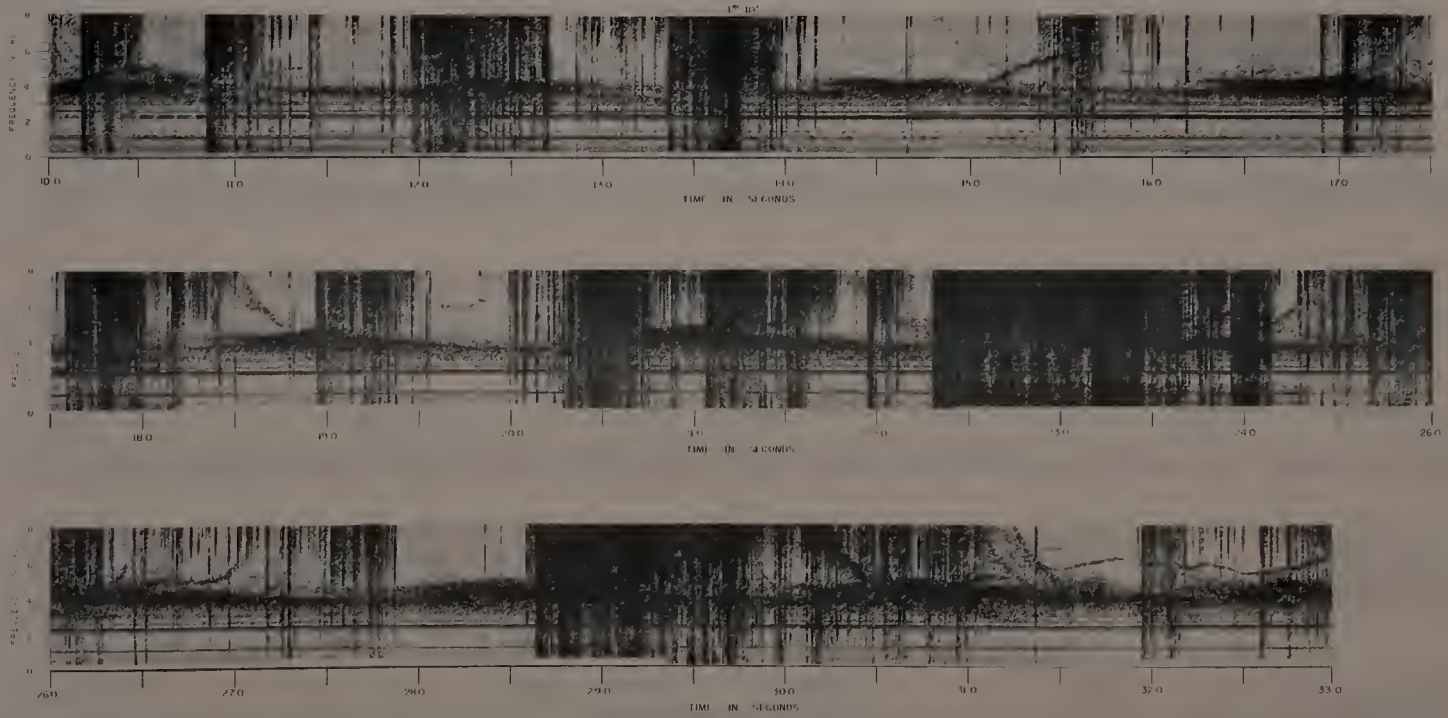
30 JUNE 1957
1735 UT



30 JUNE 1957
1735 UT (PLATE I)



30 JUNE 1957
1735 UT (PLATE II)



UNUSUAL VLF EMISSIONS ASSOCIATED WITH STRONG MAGNETIC DISTURBANCE

S. C. 11 FEBRUARY 1958 AT 01:26 U.T.

FEBRUARY 12, 1958

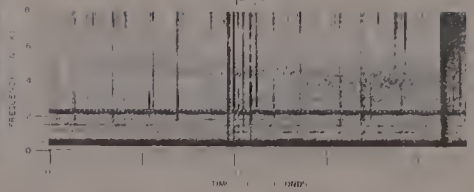
1835 UT

SECTION VI

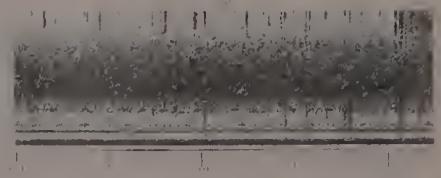
FOUR MONTH SYNOPTIC SURVEY OF VLF NOISES

2 MARCH 1957
1735 UT

1835 UT

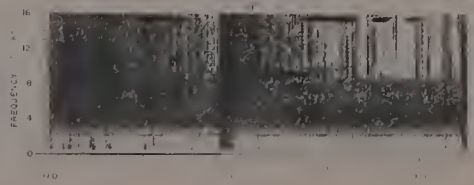


1935 UT



2035 UT

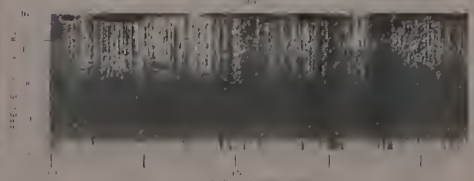
2135 UT



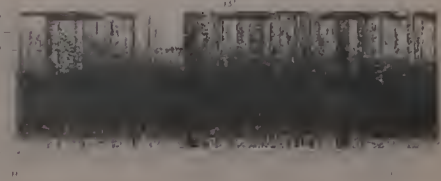
2235 UT

3 MARCH 1957
0035 UT

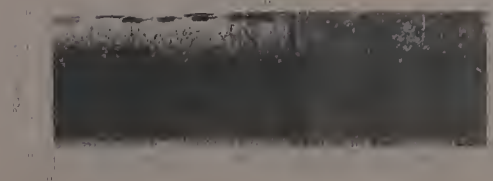
0135 UT



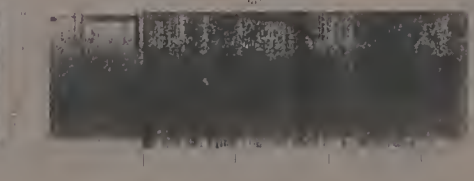
0235 UT



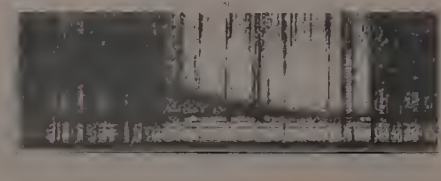
0335 UT



0435 UT

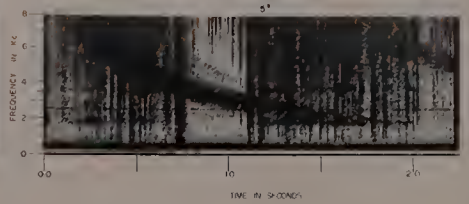


0535 UT



3 MARCH 1957
0635 UT

0835 UT



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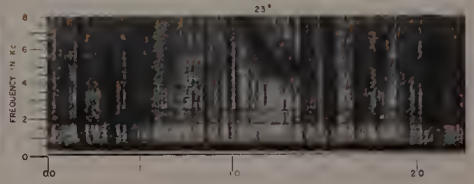
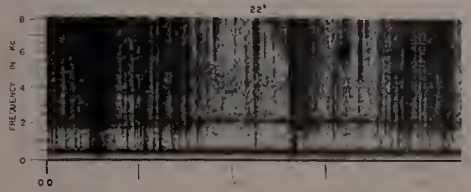
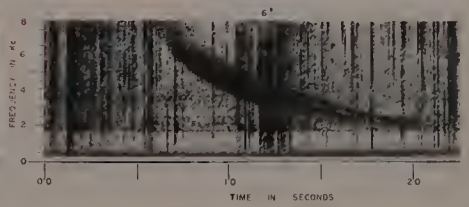


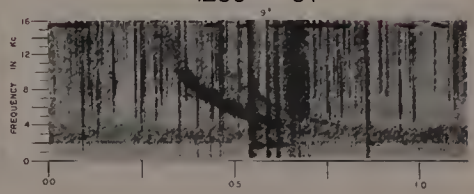
1035 UT



1135 UT



1235 UT



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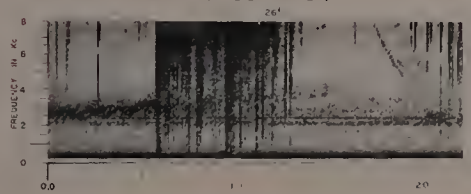
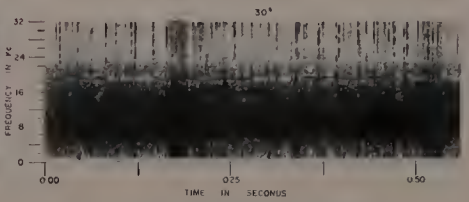
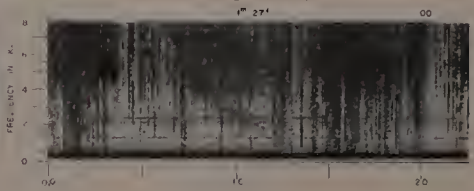


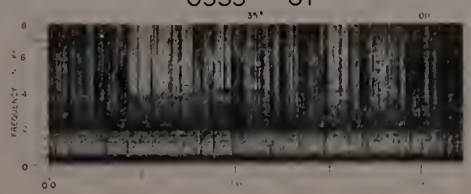
2235 UT



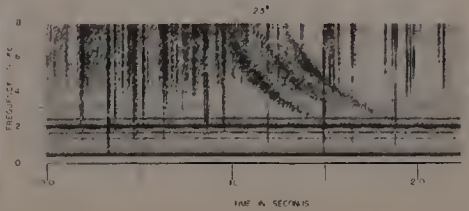
4 MARCH 1957
1235 UT



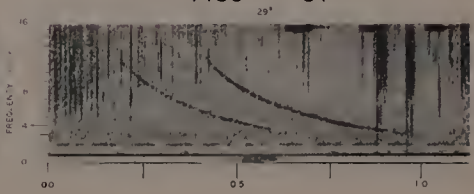
5 MARCH 1957
0535 UT



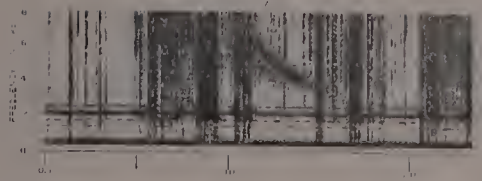
6 MARCH 1957
1235 UT



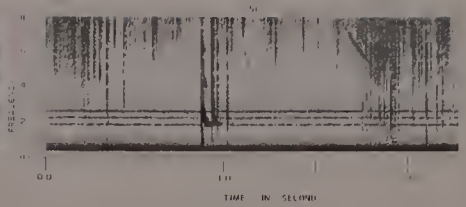
1435 UT



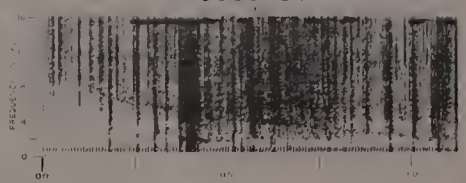
7 MARCH 1957
0535 UT



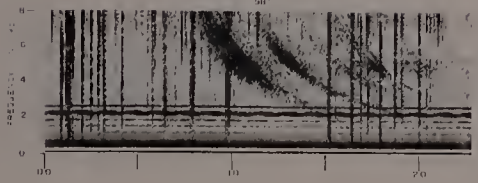
1235 UT



8 MARCH 1957
0935 UT



1235 UT



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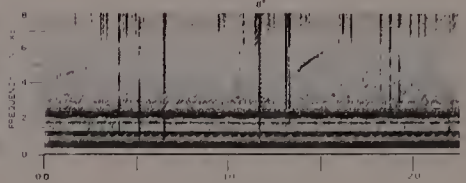
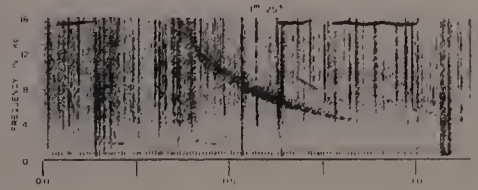
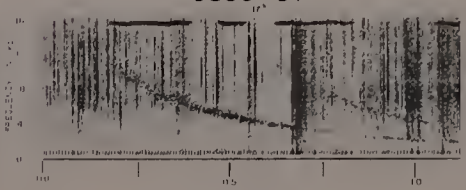


9 MARCH 1957
0435 UT

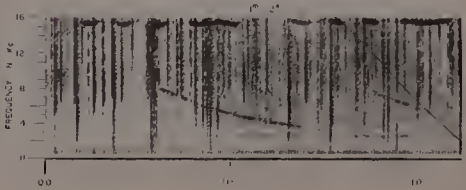
0635 UT



0835 UT



1135 UT



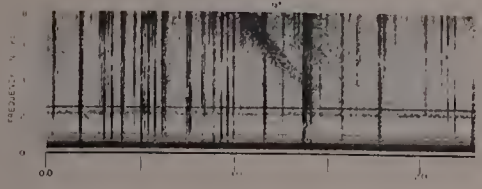
1235 UT

10 MARCH 1957
0735 UT

0835 UT

10 MARCH 1957

1135 UT



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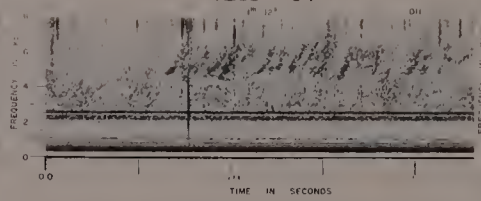
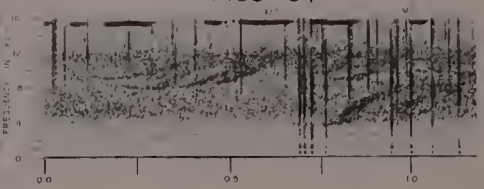
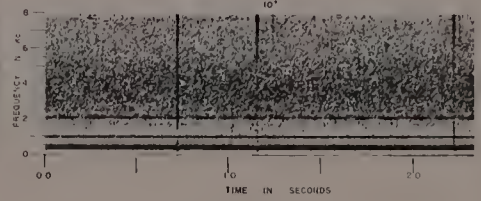


1435 UT

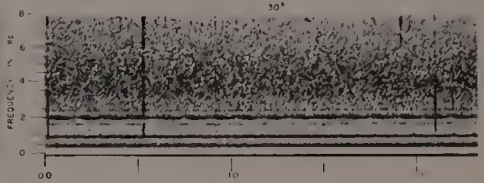


1535 UT

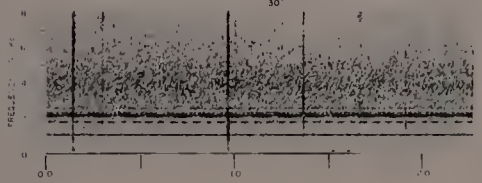
1635 UT



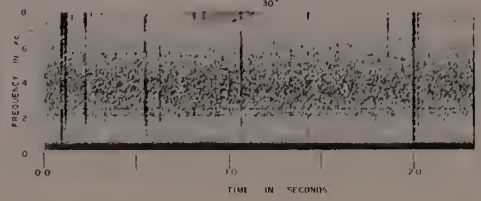
1735 UT



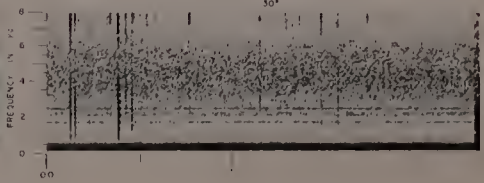
1835 UT



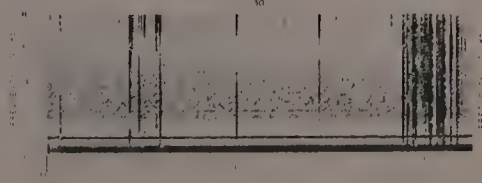
1935 UT



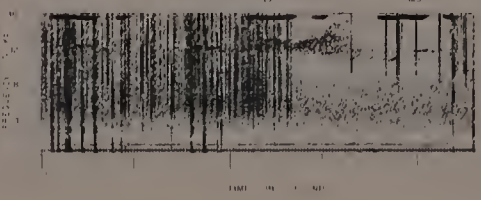
2035 UT



2135 UT

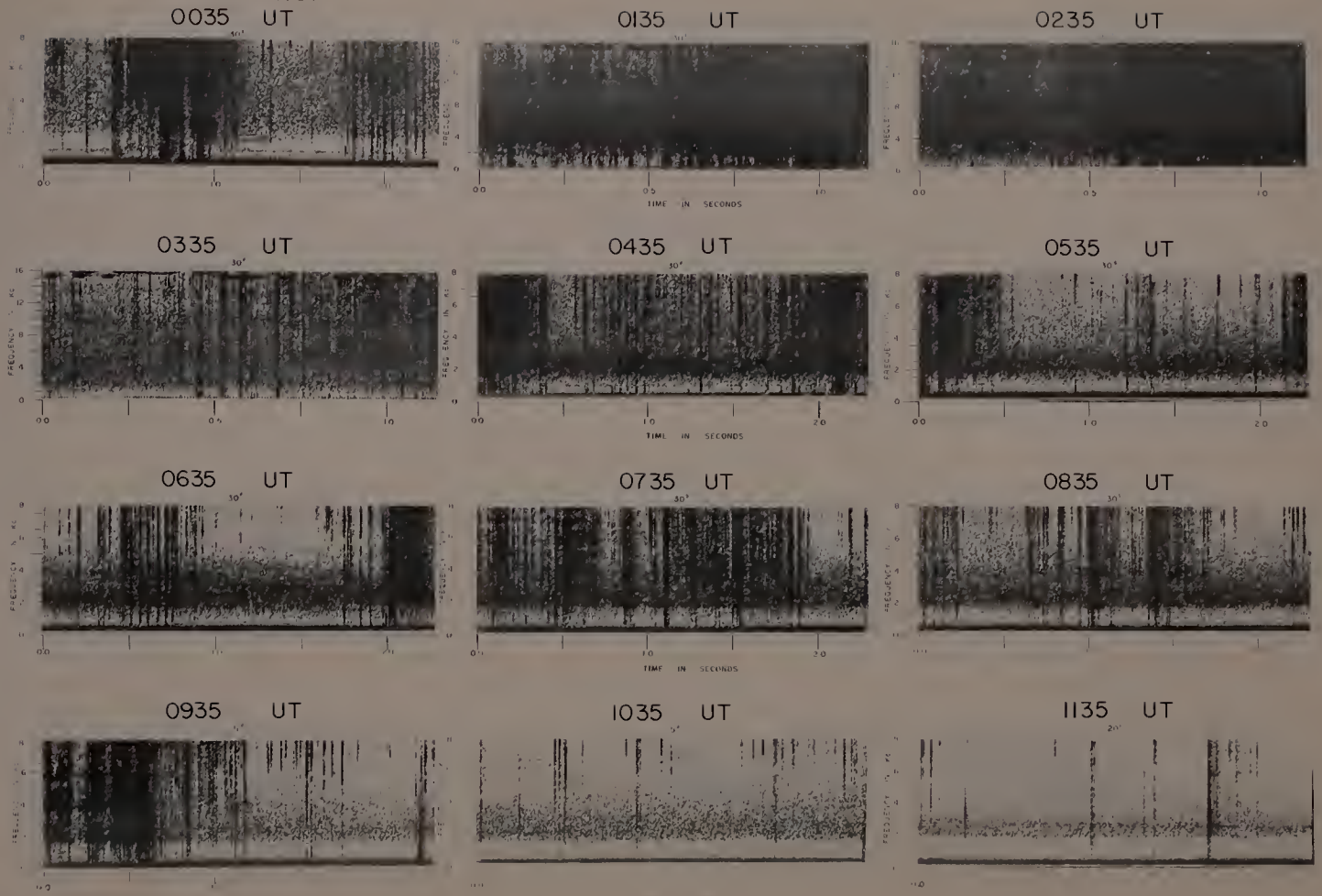


2235 UT

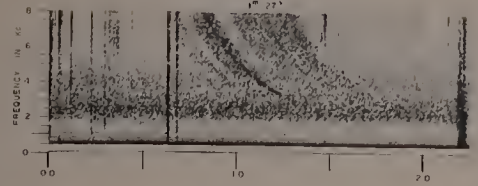


2335 UT

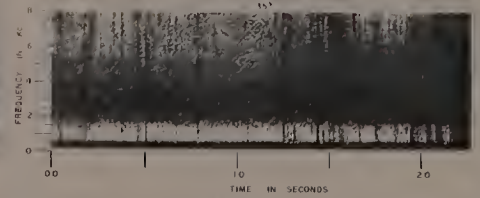
11 MARCH 1957



11 MARCH 1957
1235 UT

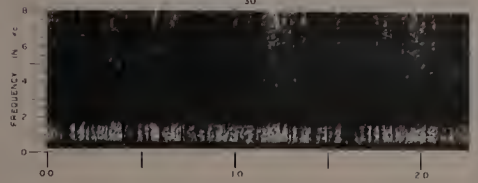


12 MARCH 1957
0335 UT



0435 UT

0535 UT



13 MARCH 1957
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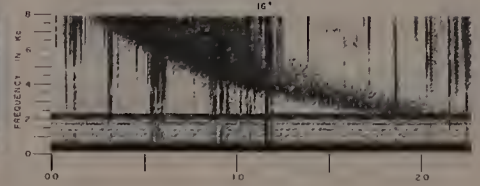

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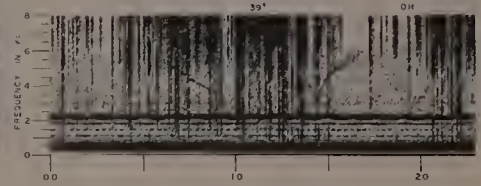

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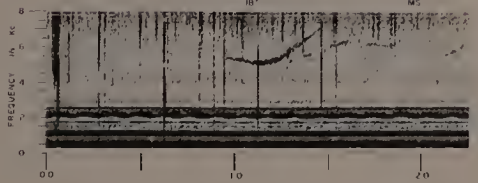
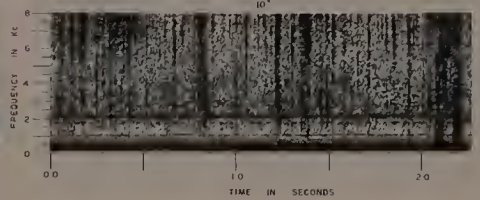
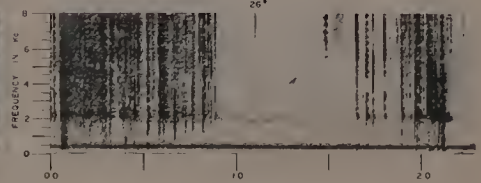


1835 UT

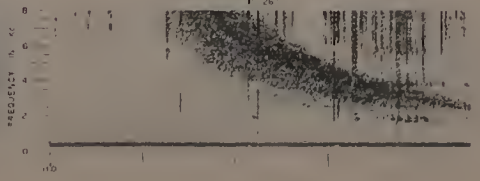


14 MARCH 1957
0335 UT

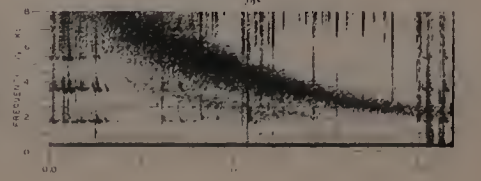


0335 UT

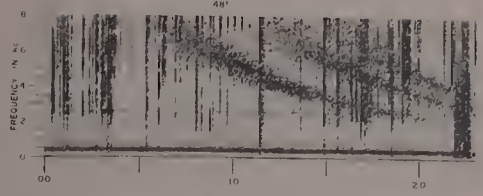
0735 UT



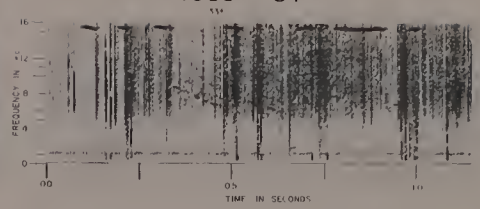
0835 UT



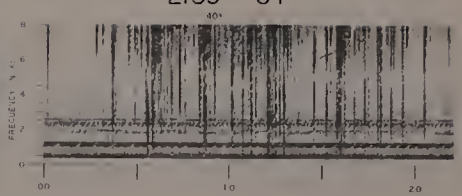
14 MARCH 1957
1235 UT



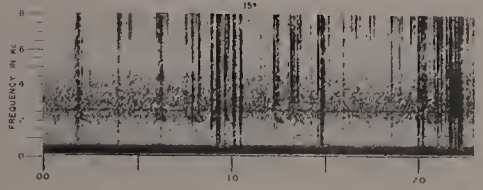
15 MARCH 1957
1635 UT



2135 UT



16 MARCH 1957
0435 UT



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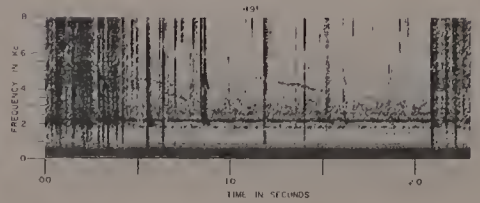

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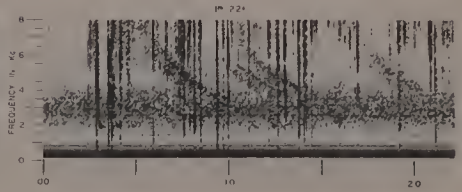

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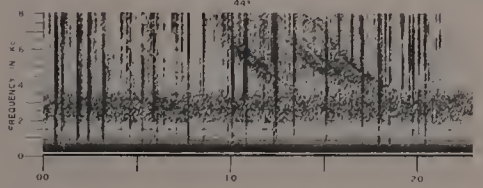

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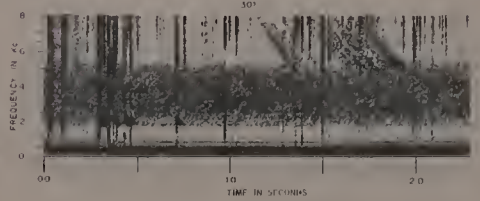

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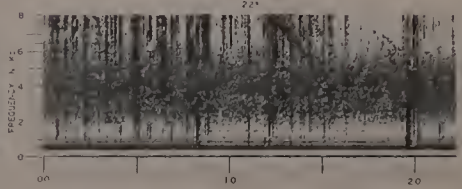
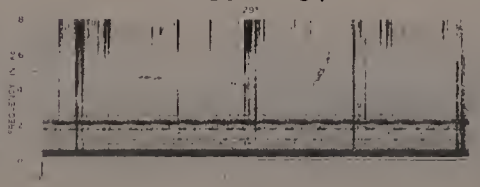
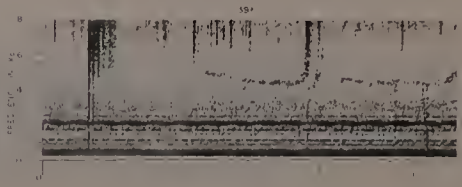


1035 UT

2335 UT

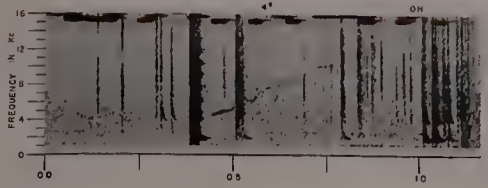


2335 UT



17 MARCH 1957

0435 UT



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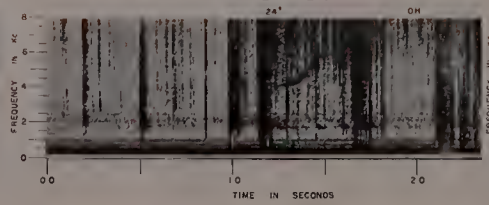

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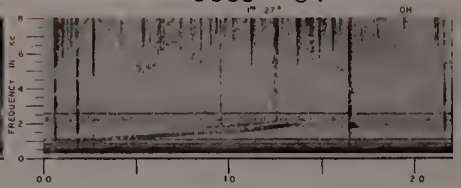

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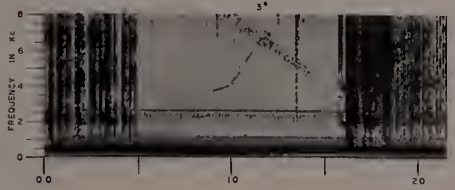
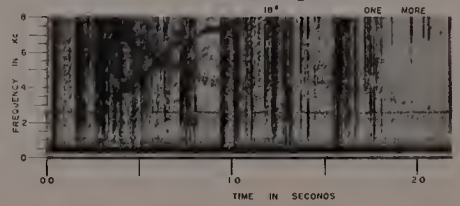
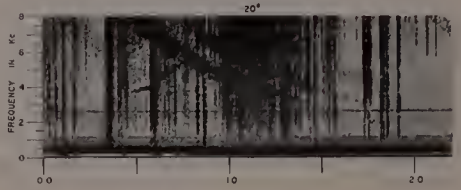


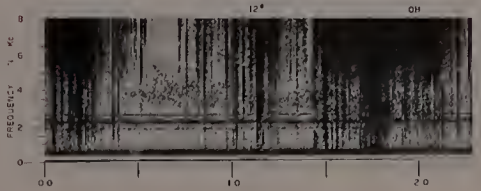
1135 UT



1235 UT



1435 UT



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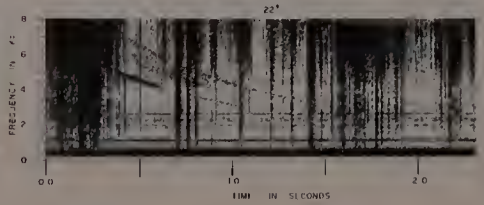

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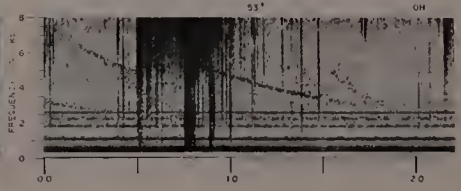
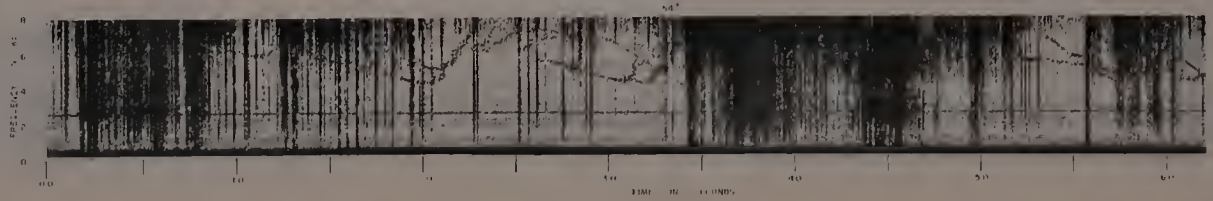
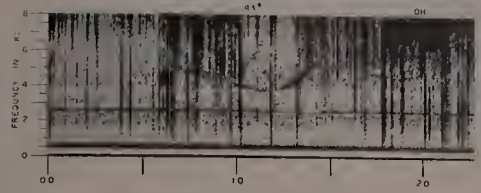


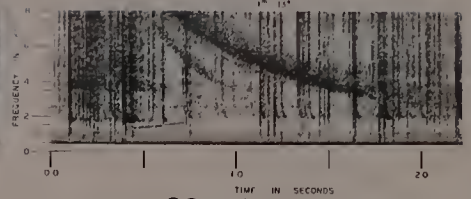
1935 UT



17 MARCH 1957
2035 UT



18 MARCH 1957
0635 UT



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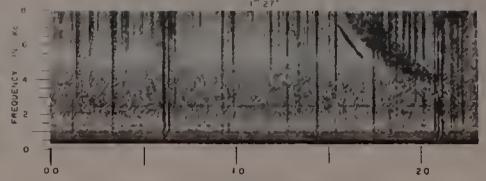

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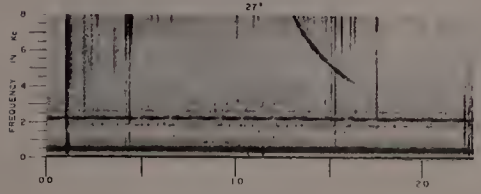
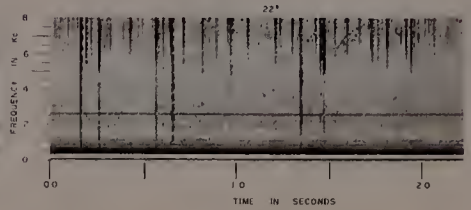


20 MARCH 1957
1235 UT



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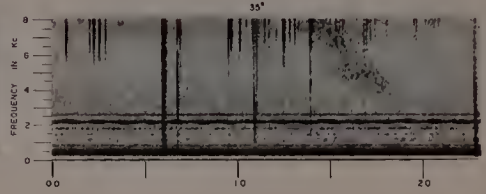
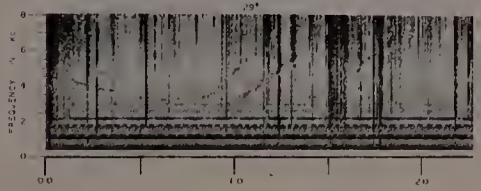


21 MARCH 1957
2035 UT



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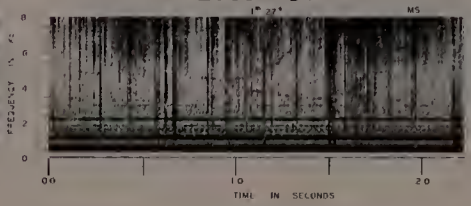

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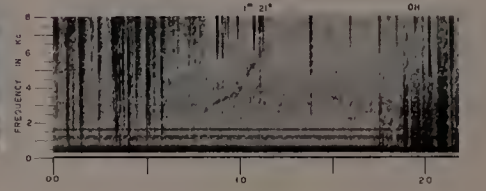
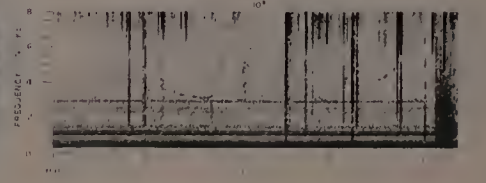


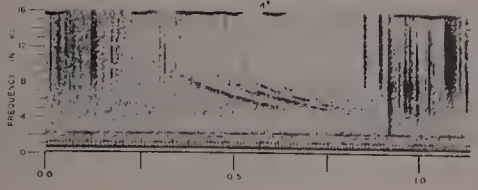
22 MARCH 1957
0035 UT

0235 UT

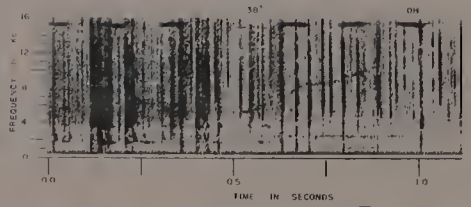
2135 UT



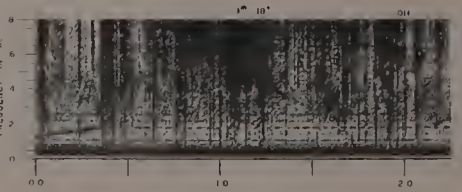
23 MARCH 1957
0135 UT



0935 UT



25 MARCH 1957
1135 UT



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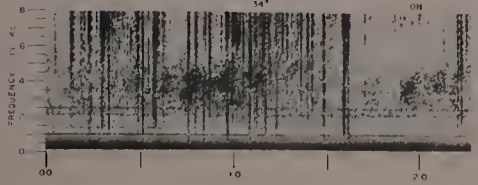
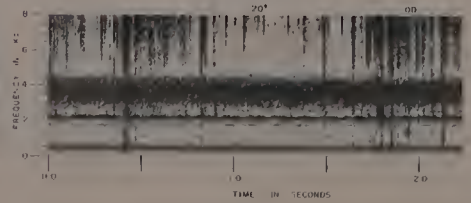
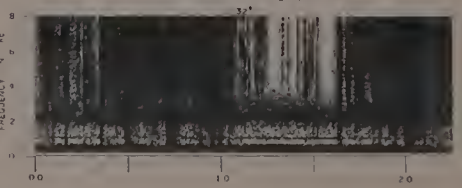


27 MARCH 1957
0135 UT



28 MARCH 1957
0135 UT



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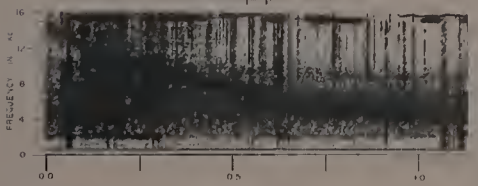

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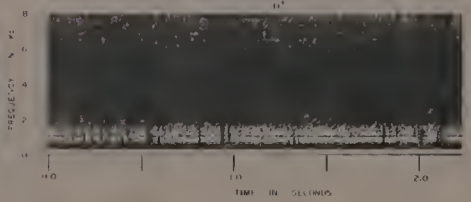

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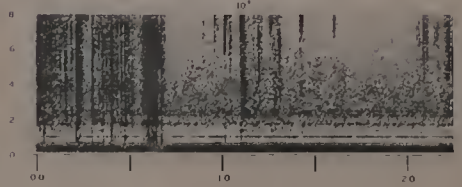

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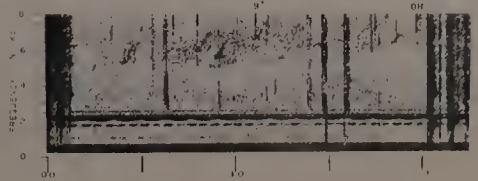

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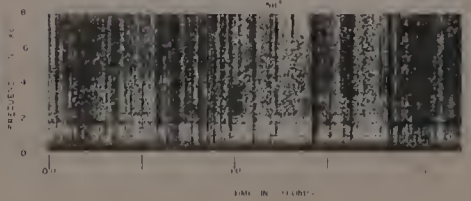

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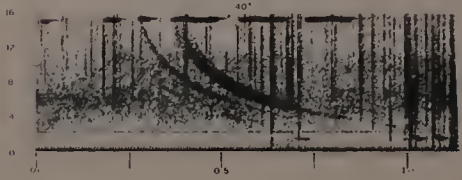
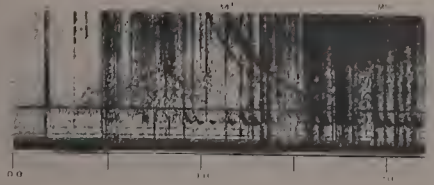


28 MARCH 1957
0835 UT



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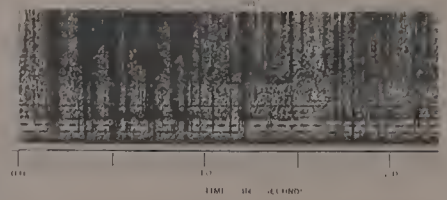

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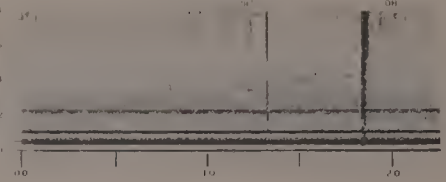
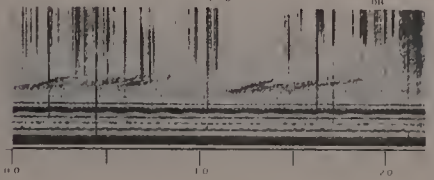


29 MARCH 1957
0035 UT



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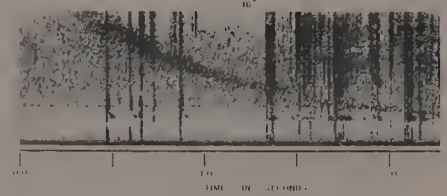

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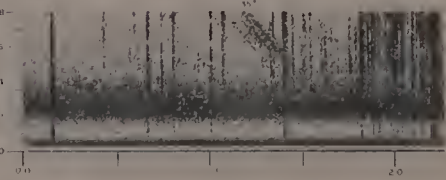

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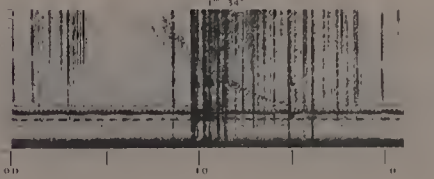

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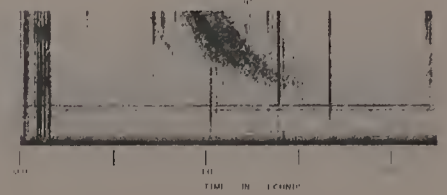

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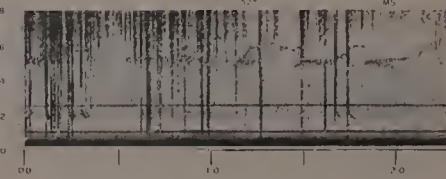
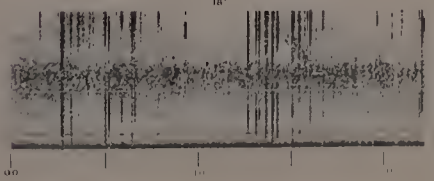
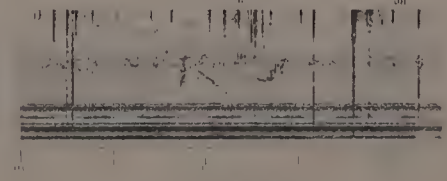


1435 UT

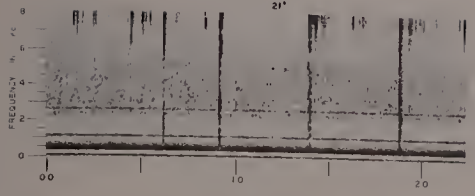


1635 UT



2035 UT

29 MARCH 1957
2335 UT



30 MARCH 1957
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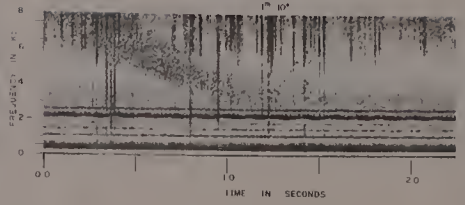

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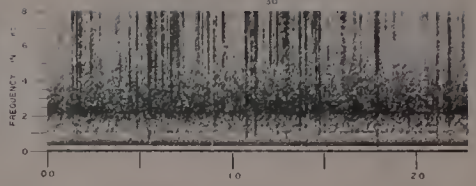

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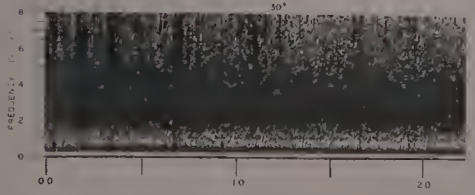

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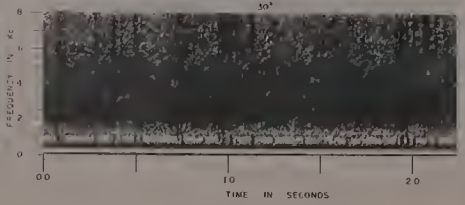

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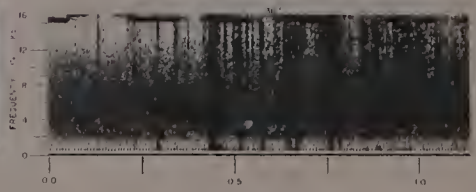

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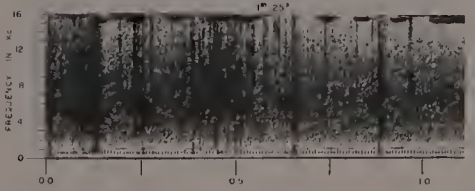

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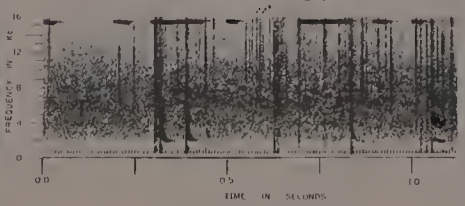
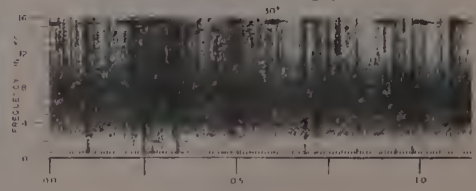
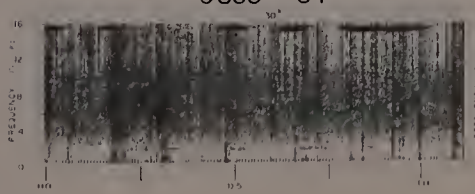


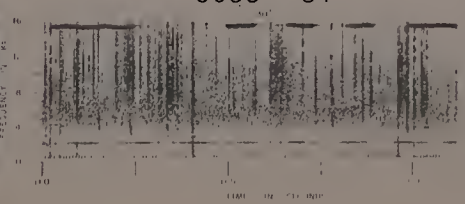
0735 UT



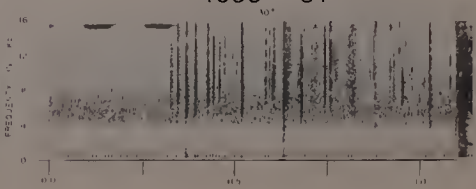
0835 UT



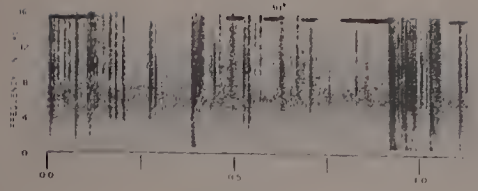
0935 UT



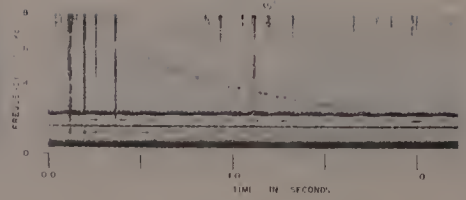
1035 UT



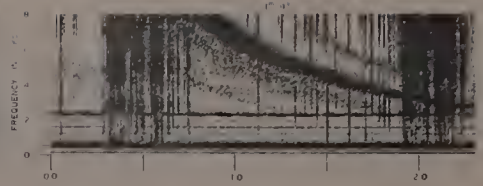
30 MARCH 1957
1135 UT



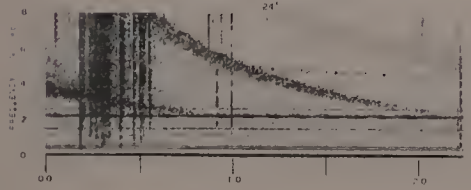
2235 UT



2335 UT



31 MARCH 1957
0035 UT



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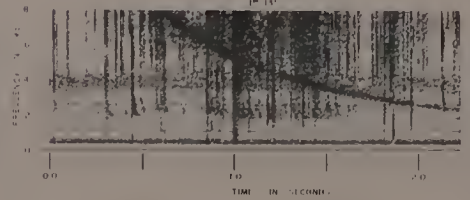
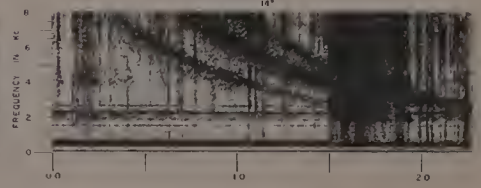
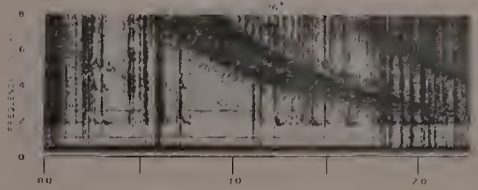


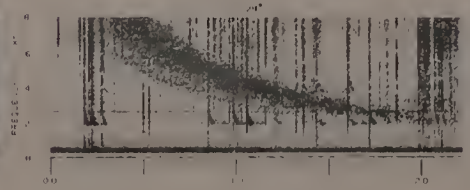
0535 UT



0635 UT



0835 UT



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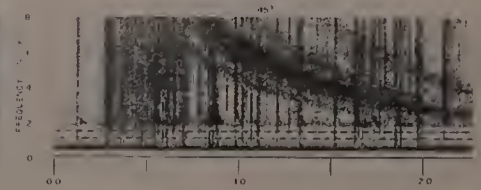
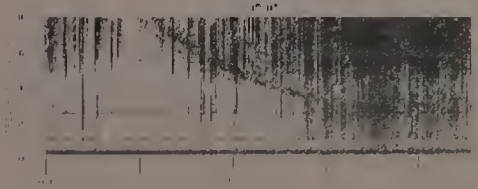


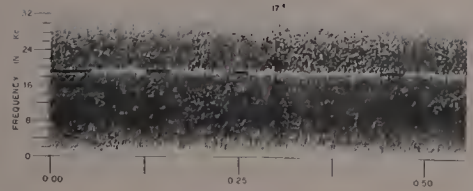
1435 UT



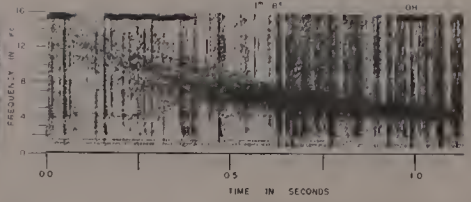
1 APRIL 1957
2335 UT

2 APRIL 1957
0035 UT

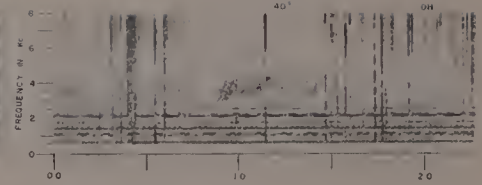
2 APRIL 1957
0535 UT



5 APRIL 1957
0535 UT



1335 UT



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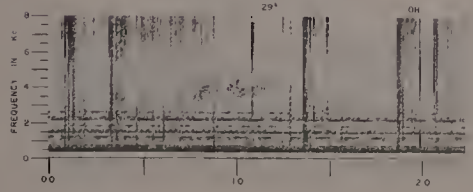

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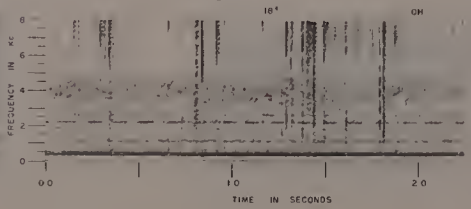
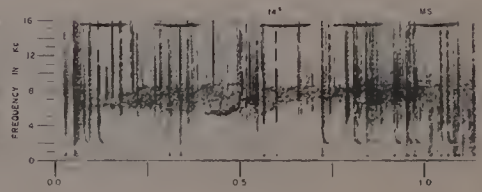


6 APRIL 1957
1035 UT



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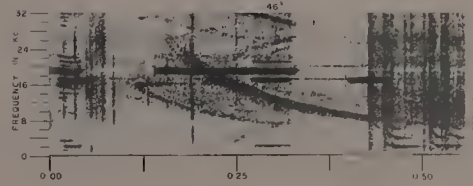

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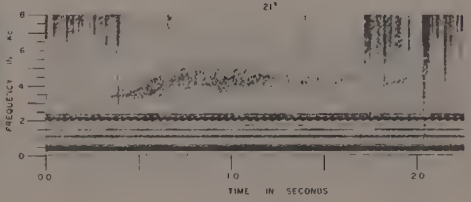
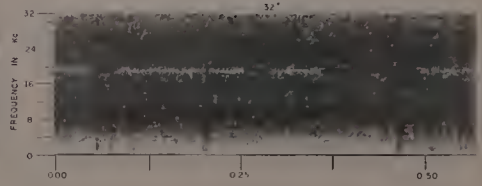
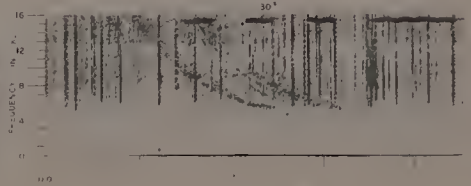


7 APRIL 1957
0235 UT



0335 UT

0835 UT



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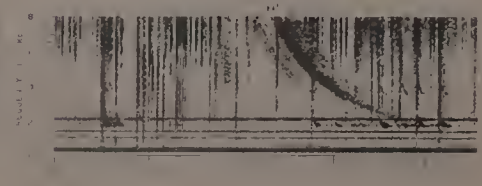
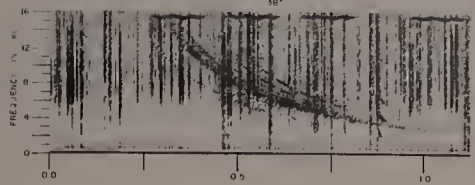
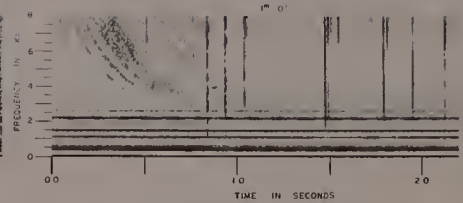


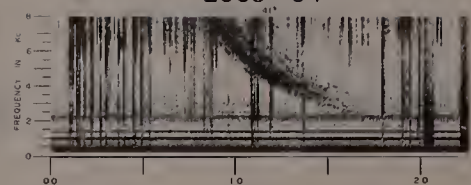
7 APRIL 1957
1135 UT



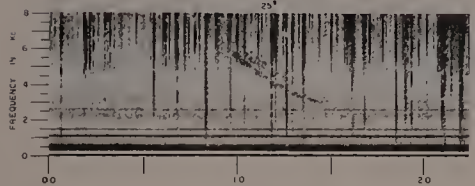
1335 UT



9 APRIL 1957
2335 UT



10 APRIL 1957
0035 UT



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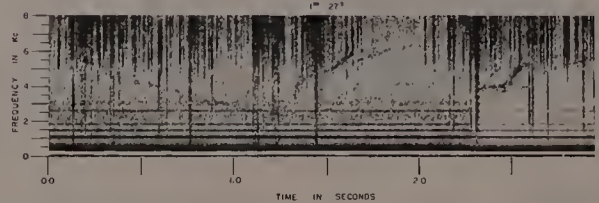

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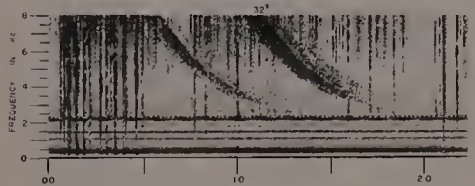

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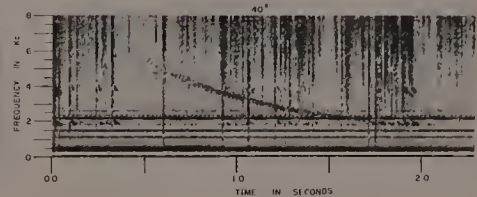

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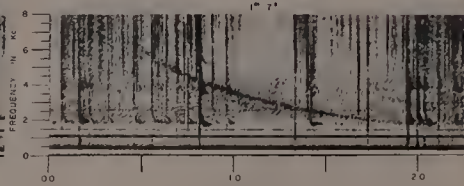

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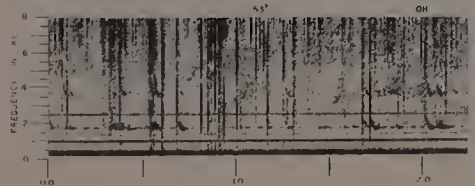

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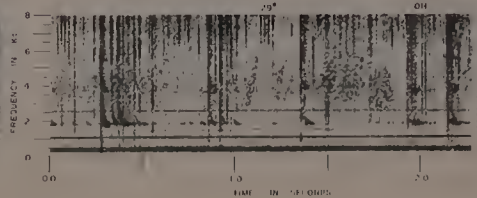

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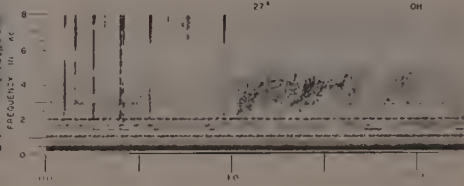
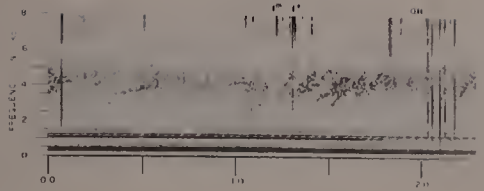
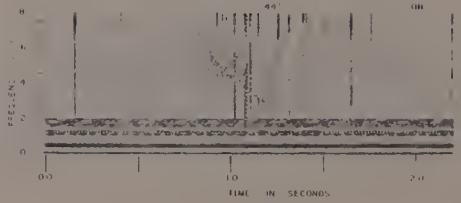


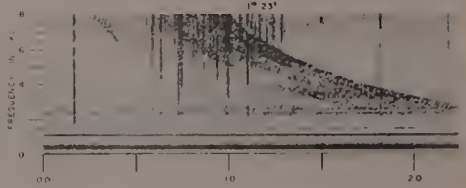
10 APRIL 1957
1535 UT



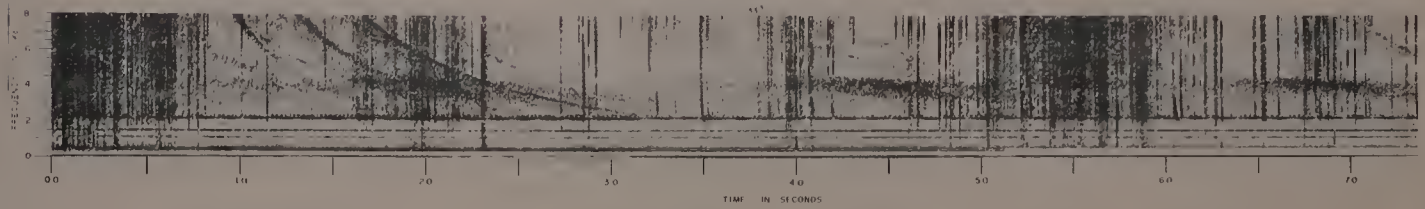
1635 UT



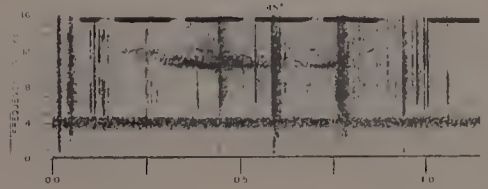
11 APRIL 1957
0335 UT



0135 UT



0235 UT



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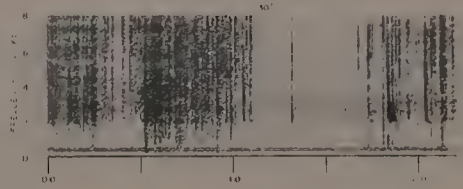

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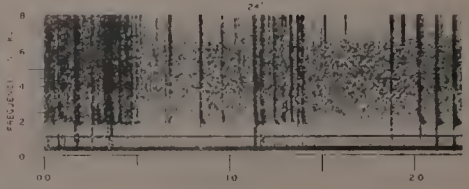

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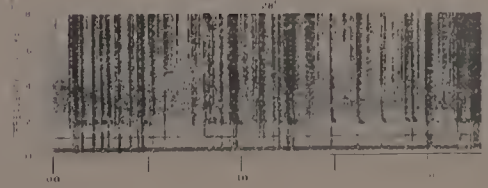
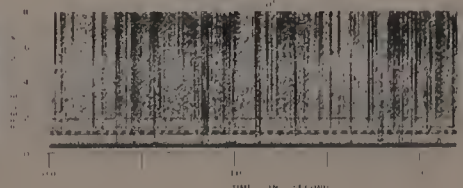
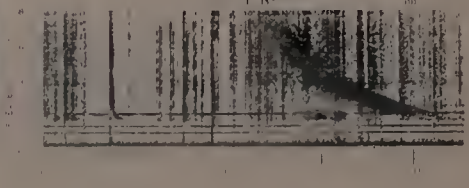


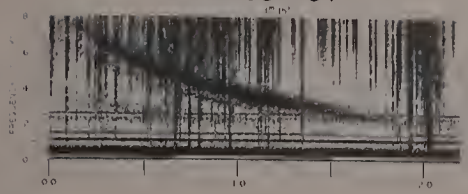
1935 UT



12 APRIL 1957
0535 UT



13 APRIL 1957
0035 UT



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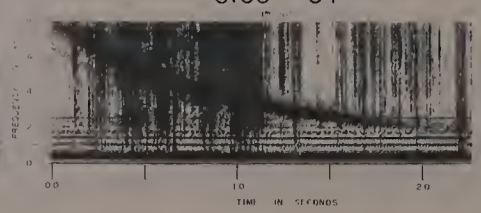
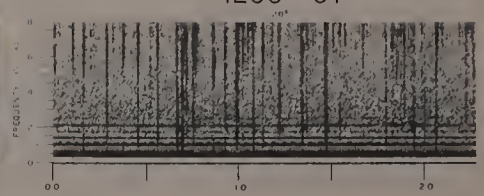
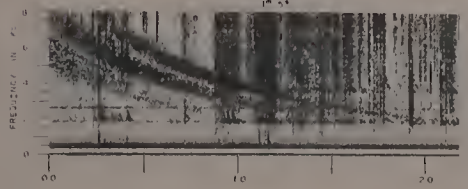


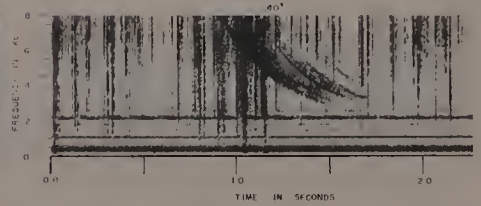
1235 UT



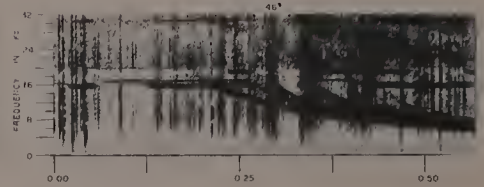
17 APRIL 1957
0535 UT



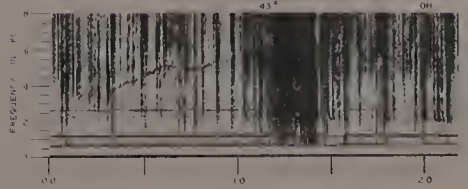
2335 UT



18 APRIL 1957
0035 UT



0135 UT



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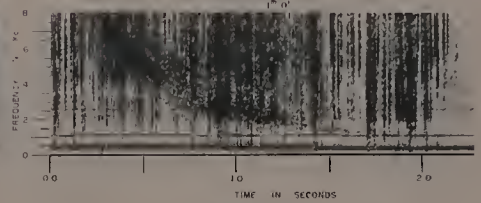
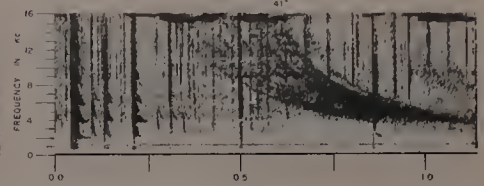
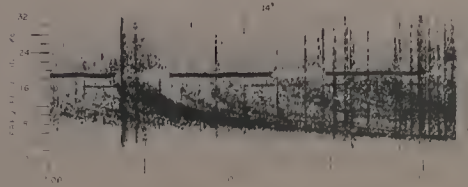


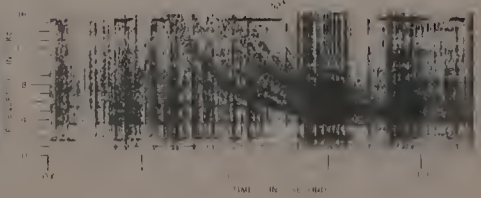
0335 UT



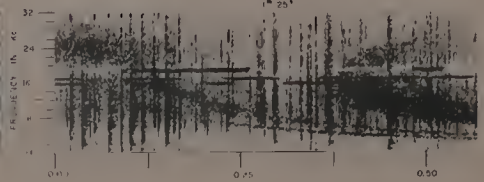
0435 UT



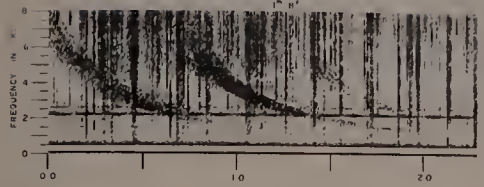
0635 UT



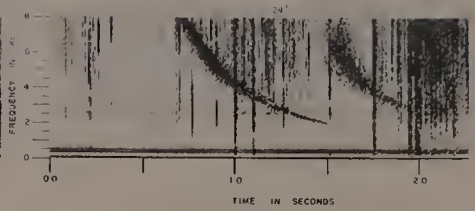
1135 UT



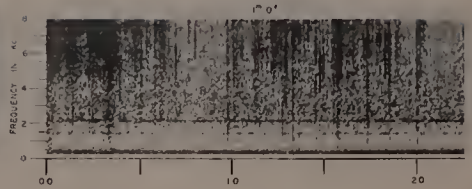
18 APRIL 1957
1335 UT



1435 UT



19 APRIL 1957
1335 UT



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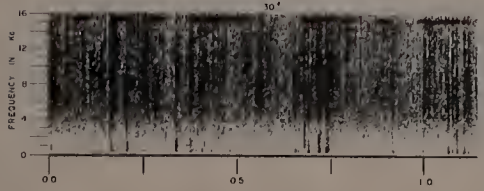
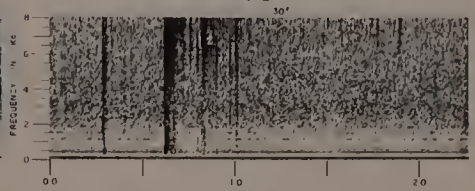
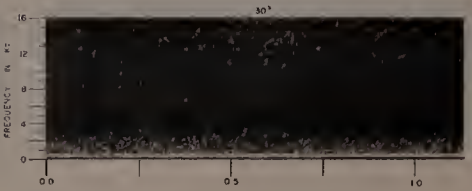


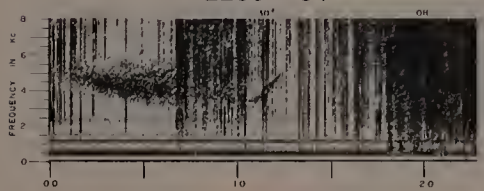
1635 UT



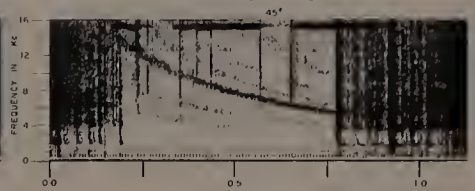
1735 UT



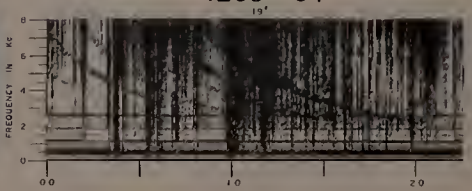
2235 UT



20 APRIL 1957
1035 UT

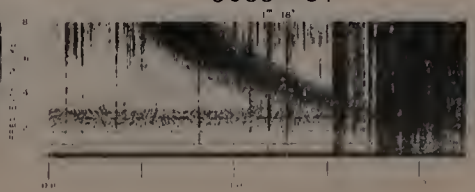


1235 UT

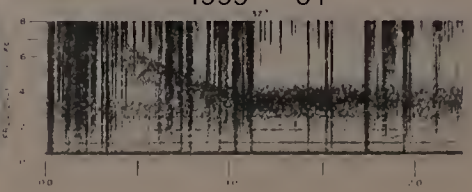


21 APRIL 1957
1335 UT

22 APRIL 1957
0935 UT

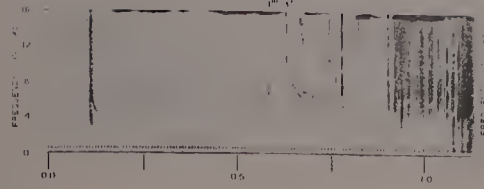


1335 UT



24 APRIL 1957

0335 UT



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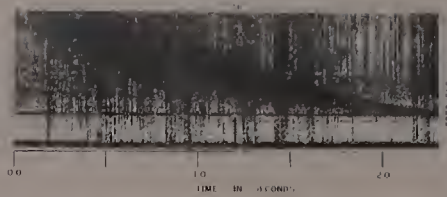

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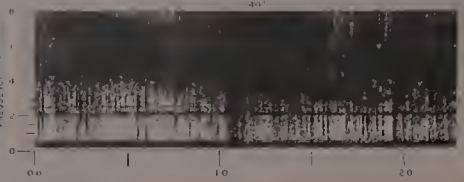

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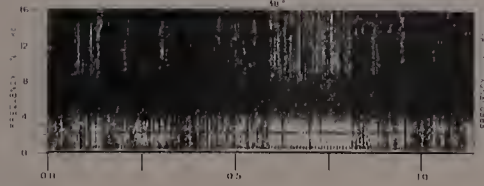
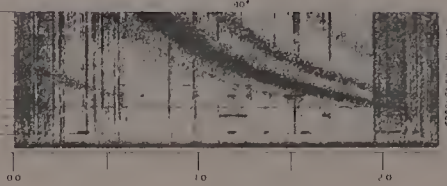
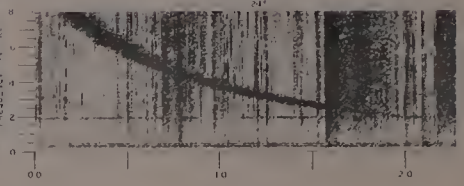


26 APRIL 1957

1135 UT

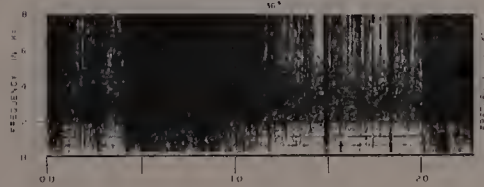


1235 UT

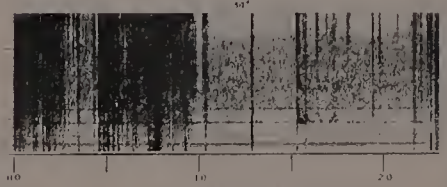


27 APRIL 1957

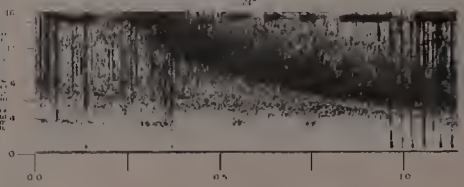
0235 UT



0735 UT



1035 UT



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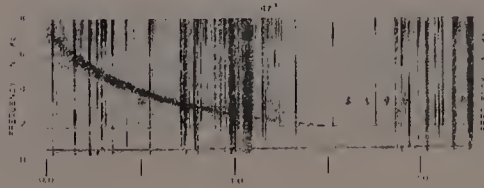
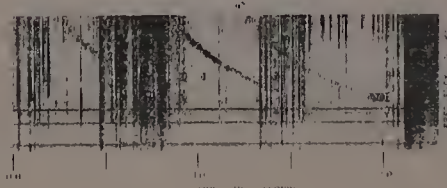


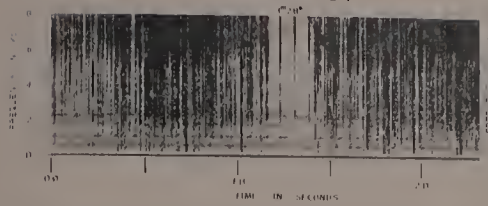
29 APRIL 1957

1235 UT

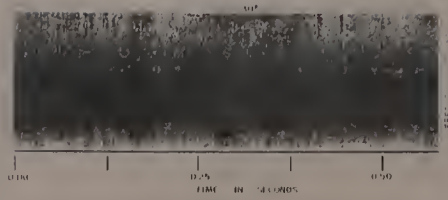


1335 UT

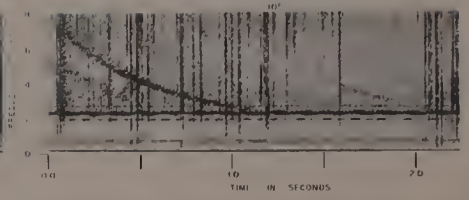
29 APRIL 1957
1435 UT



1 MAY 1957
0335 UT



1135 UT



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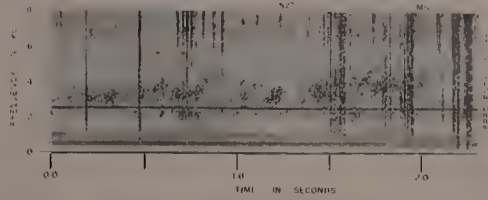

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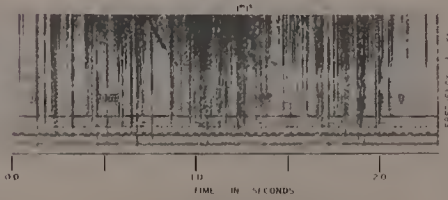
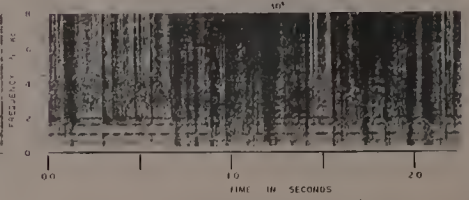
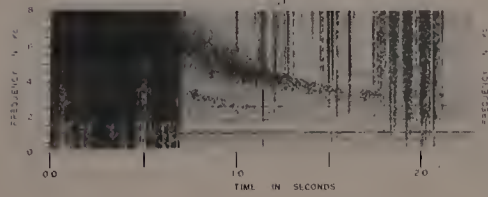


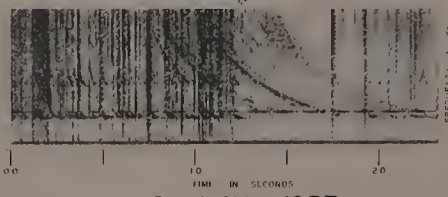
2 MAY 1957
0235 UT



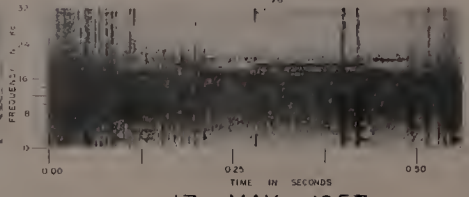
0435 UT



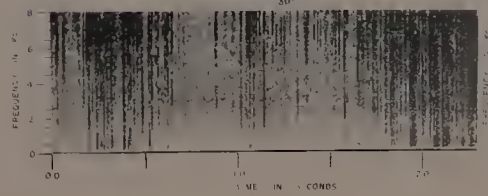
7 MAY 1957
0535 UT



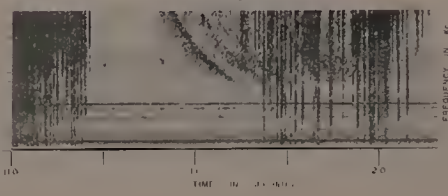
9 MAY 1957
0235 UT



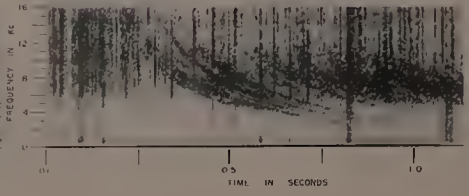
1235 UT



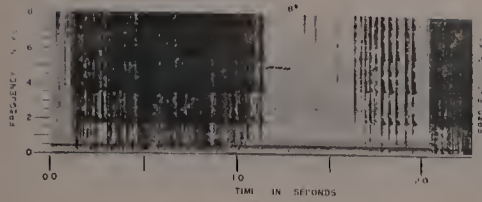
12 MAY 1957
1435 UT



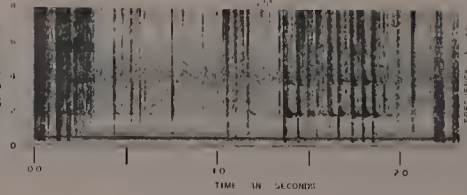
17 MAY 1957
1135 UT



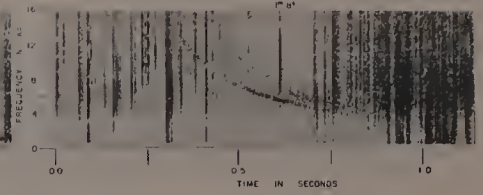
24 MAY 1957
0835 UT



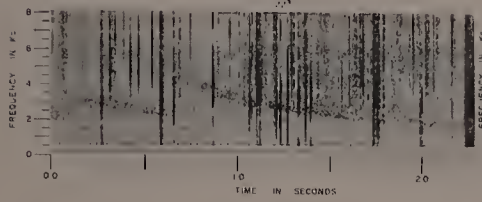
0935 UT



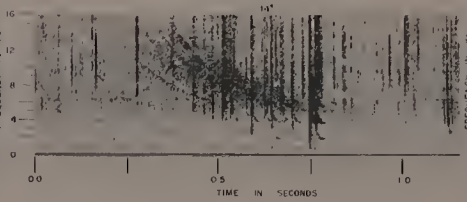
25 MAY 1957
1235 UT



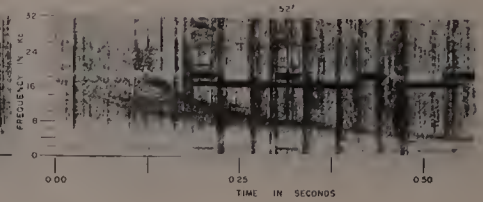
26 MAY 1957
1135 UT



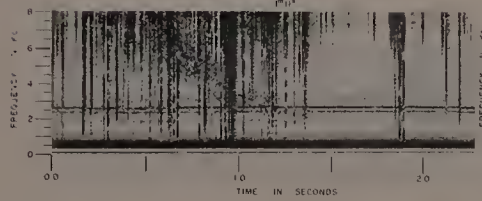
28 MAY 1957
0835 UT



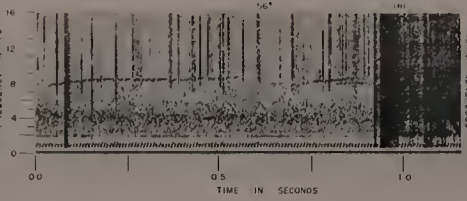
1035 UT



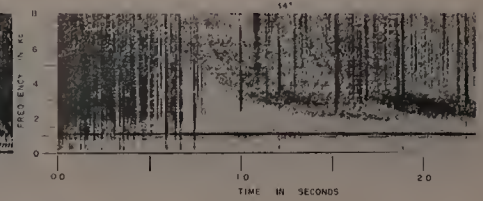
1235 UT



29 MAY 1957
0635 UT



1135 UT



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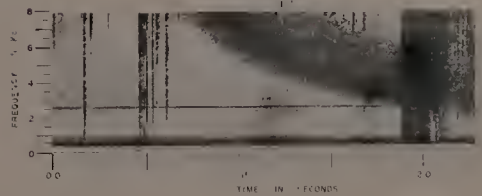
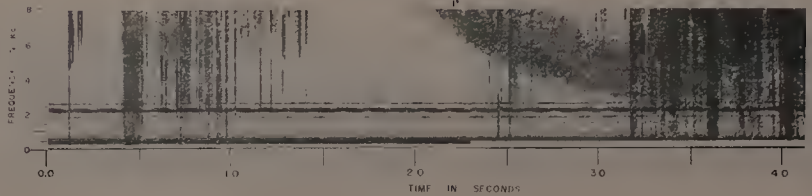
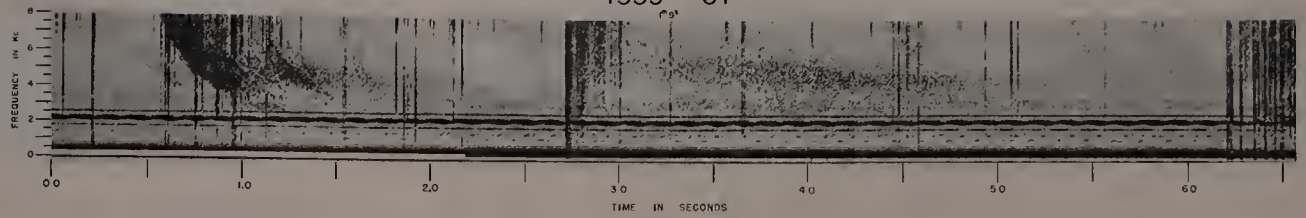


1335 UT

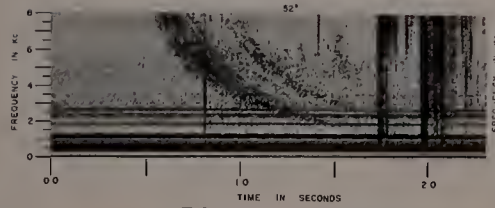


29 MAY 1957

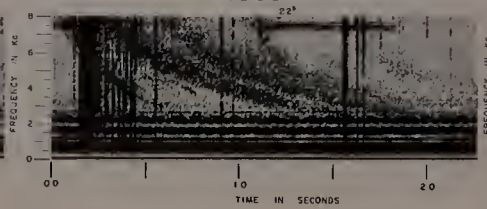
1335 UT



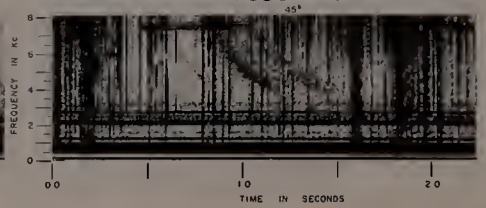
1435 UT



1535 UT

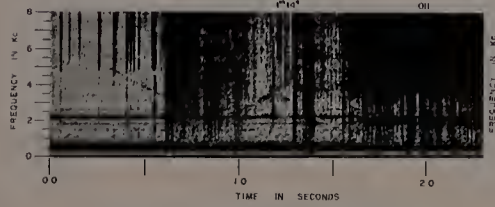


1635 UT

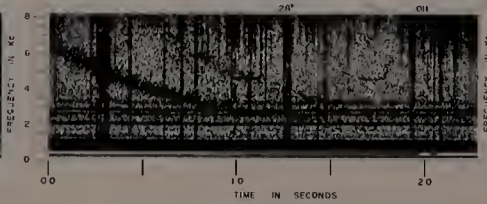


30 MAY 1957

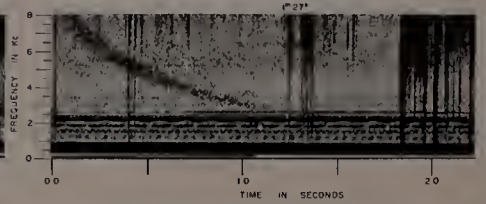
1035 UT



1235 UT

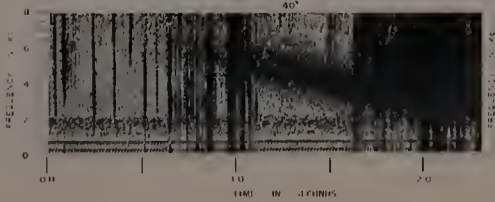


1335 UT



31 MAY 1957

1235 UT



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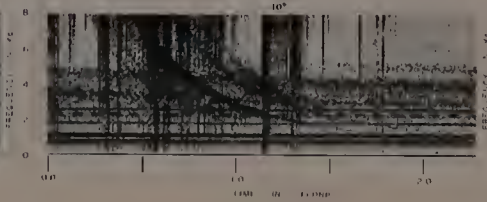
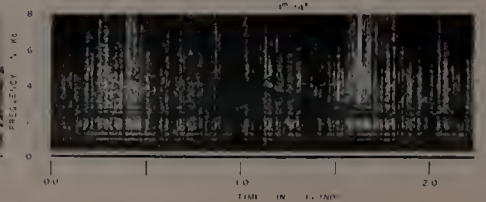
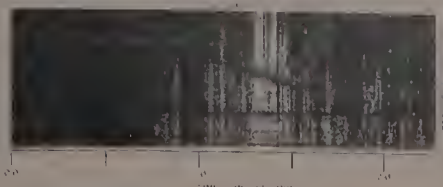


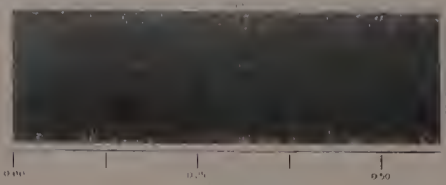
1535 UT



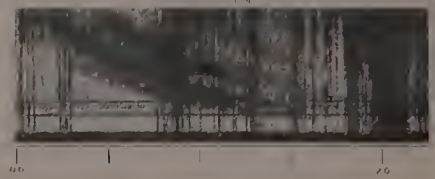
31 MAY 1957
1835 UT



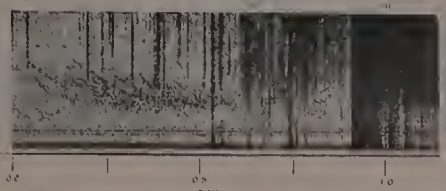
2035 UT



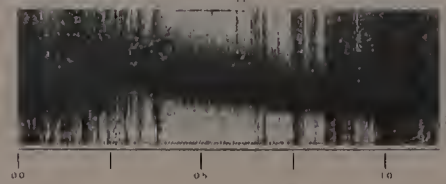
1 JUNE 1957
1235 UT



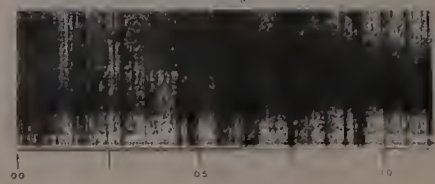
2 JUNE 1957
1635 UT



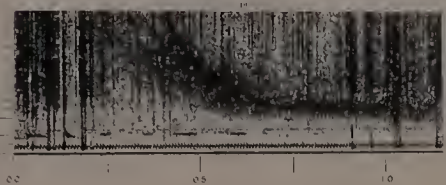
3 JUNE 1957
0035 UT



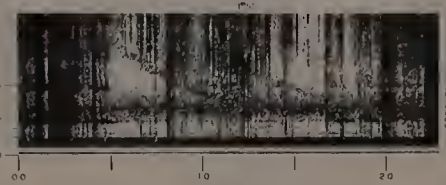
0335 UT



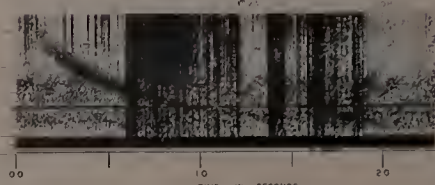
0735 UT



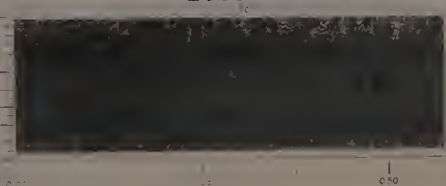
0935 UT



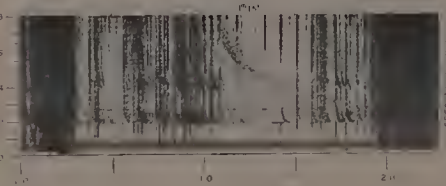
1135 UT



2035 UT



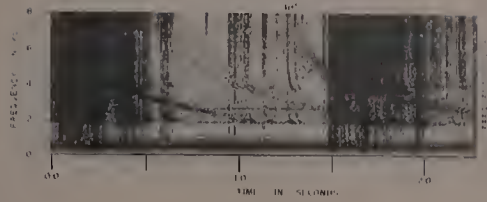
4 JUNE 1957
0435 UT



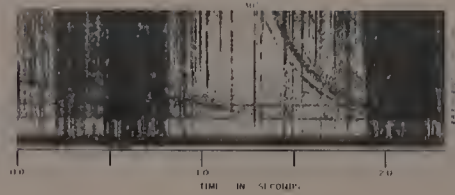
0535 UT

4 JUNE 1957

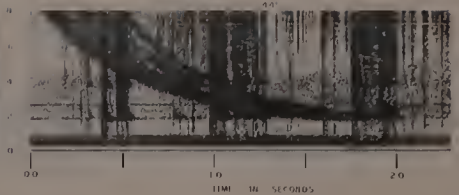
0635 UT



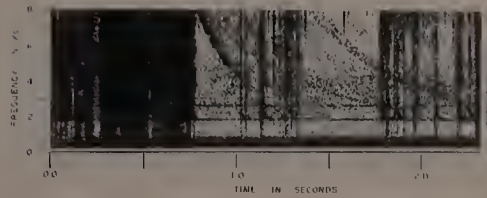
0735 UT



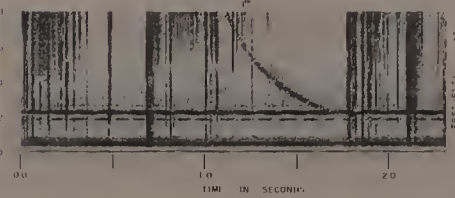
0835 UT



0935 UT

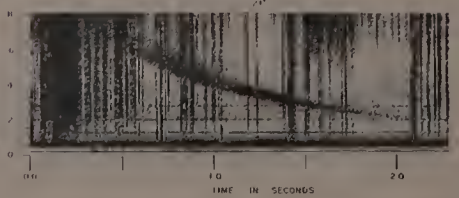


1335 UT

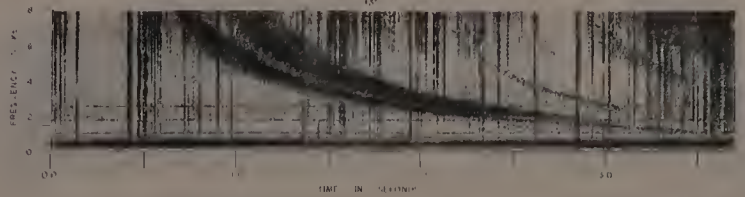


5 JUNE 1957

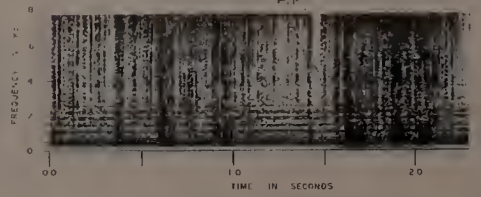
1135 UT



1235 UT



1635 UT

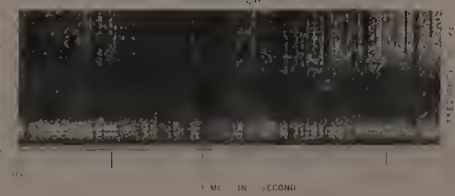


6 JUNE 1957

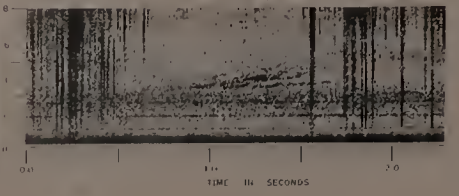
1135 UT

7 JUNE 1957

1035 UT

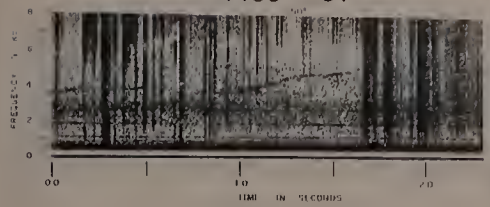


1135 UT

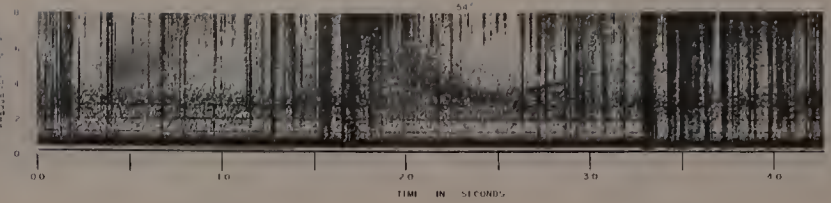


7 JUNE 1957

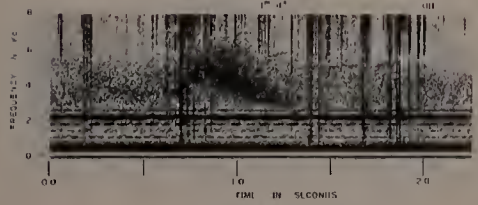
1135 UT



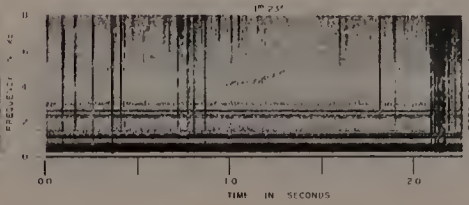
1135 UT



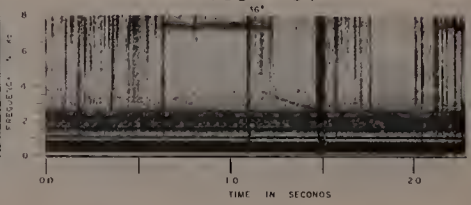
1235 UT



1435 UT

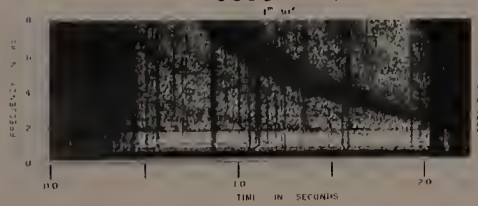


1635 UT

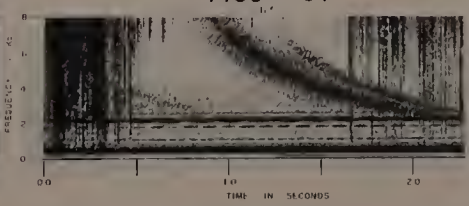


8 JUNE 1957

0635 UT



1135 UT



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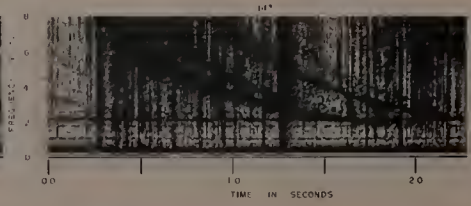
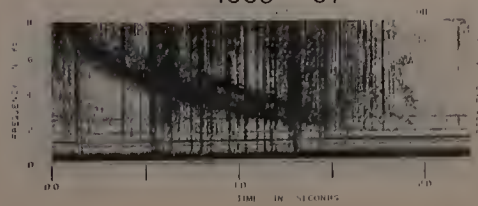


1335 UT



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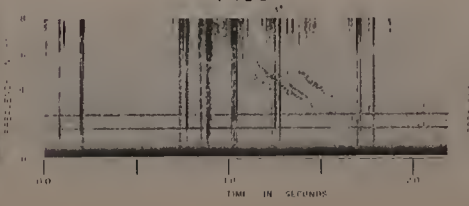
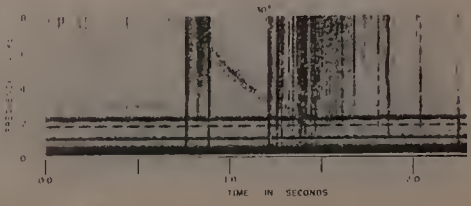
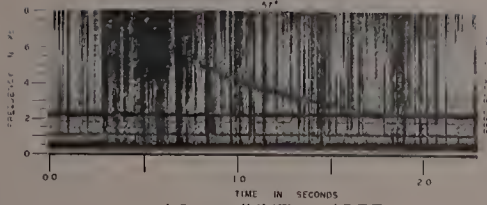


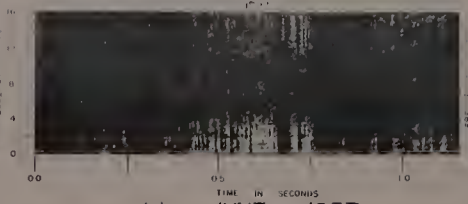
1535 UT



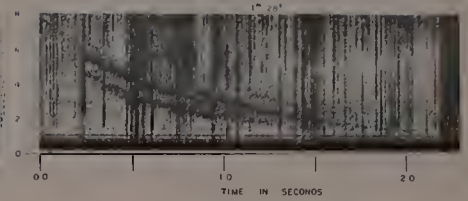
8 JUNE 1957
1635 UT



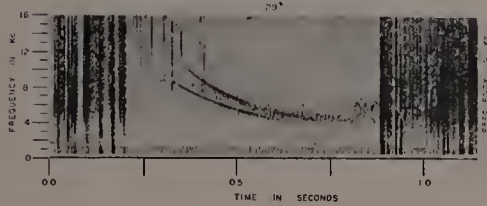
9 JUNE 1957
0335 UT



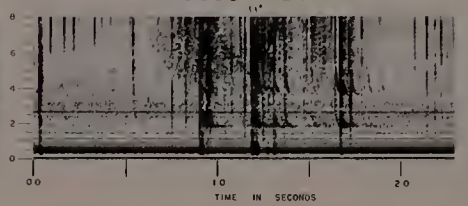
1235 UT



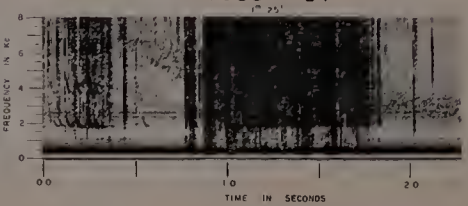
10 JUNE 1957
1435 UT



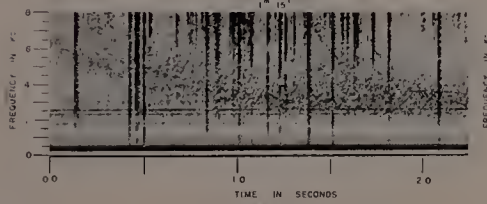
11 JUNE 1957
0935 UT



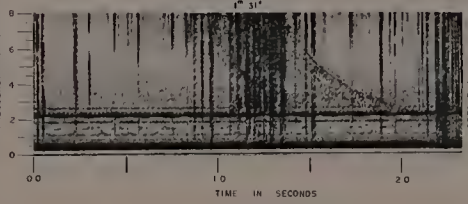
1035 UT



1135 UT



1235 UT



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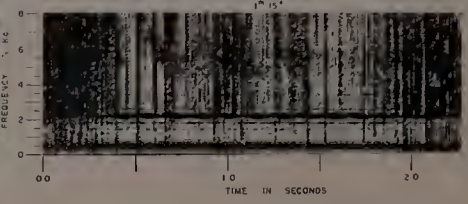
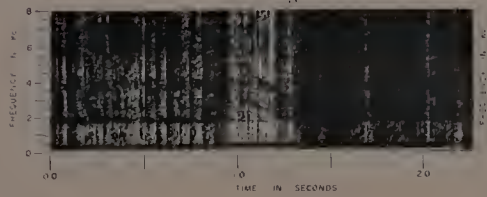


13 JUNE 1957
0835 UT



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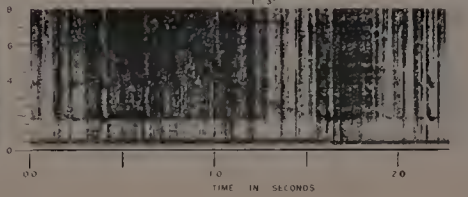
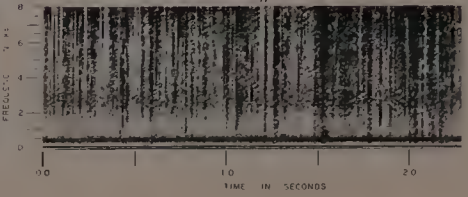
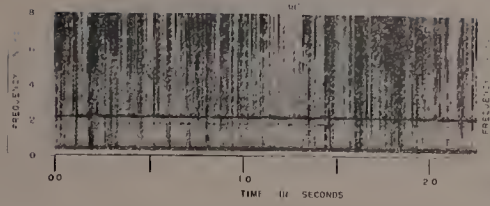


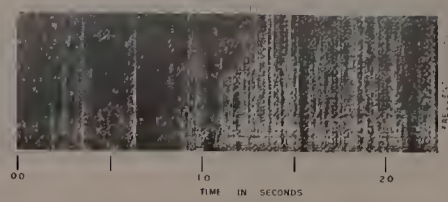
1135 UT



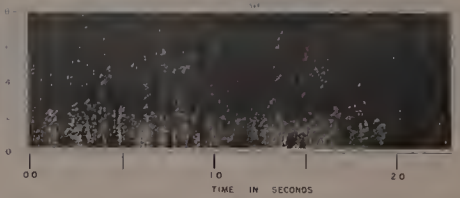
13 JUNE 1957
1235 UT



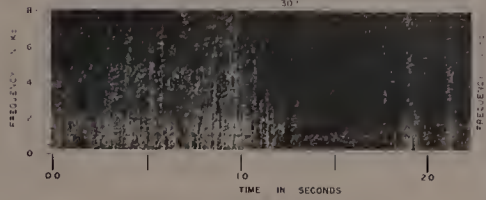
2035 UT



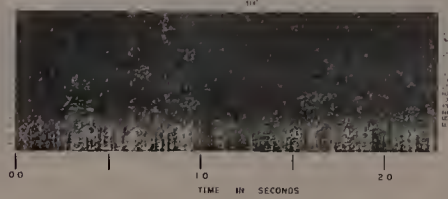
2135 UT



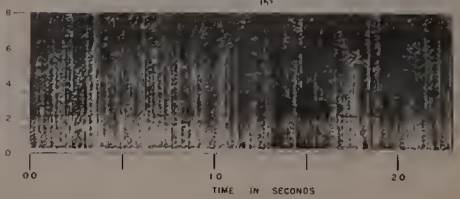
2235 UT



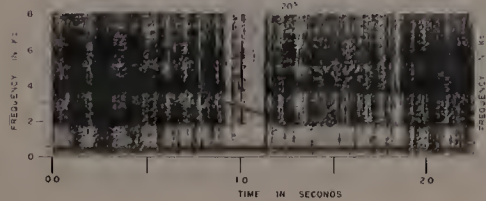
2335 UT



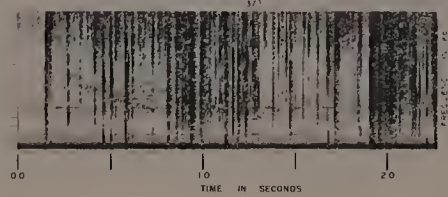
14 JUNE 1957
0035 UT



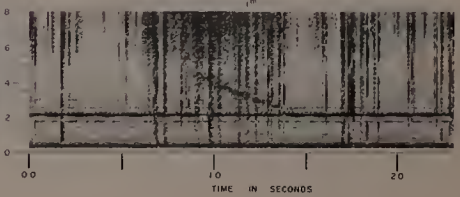
15 JUNE 1957
0935 UT



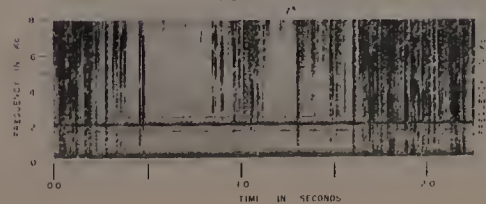
1135 UT



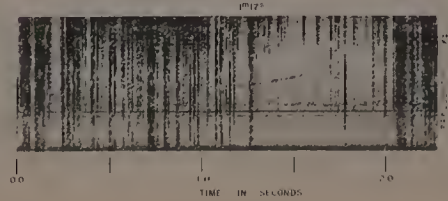
1235 UT



16 JUNE 1957
1335 UT



1335 UT



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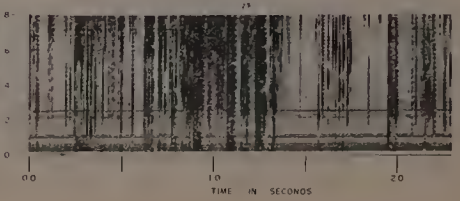
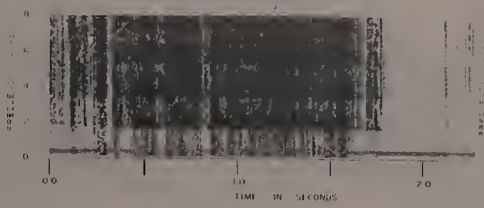
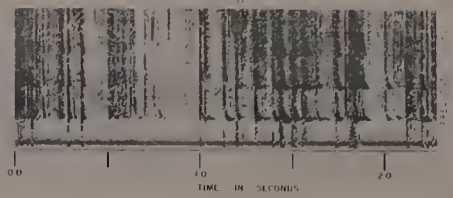


17 JUNE 1957

0735 UT



0835 UT



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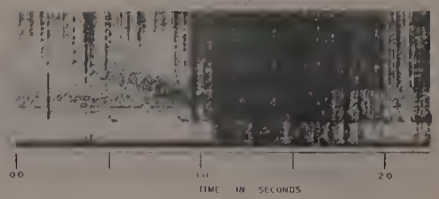

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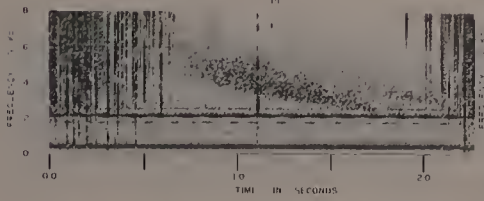

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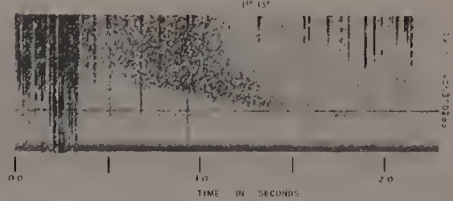

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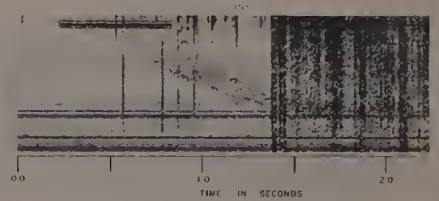
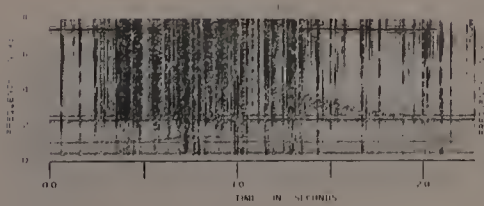
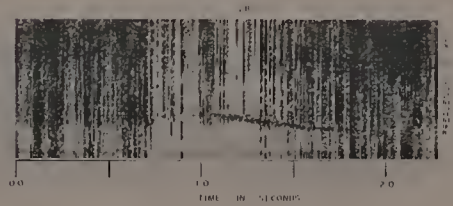


1635 UT



19 JUNE 1957

0235 UT



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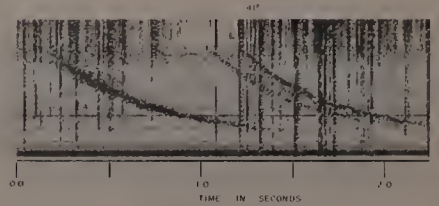

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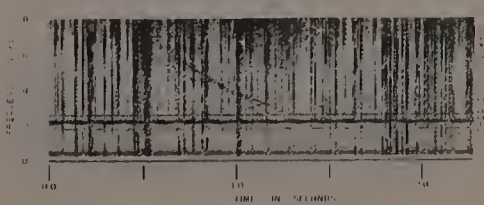

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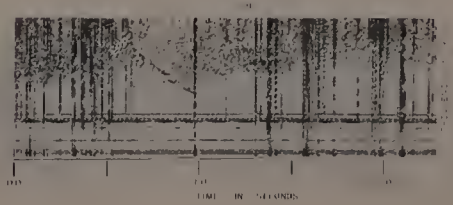

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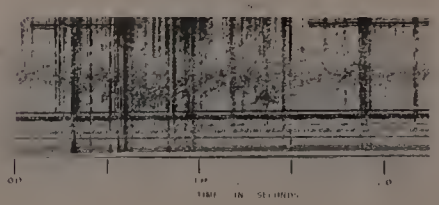

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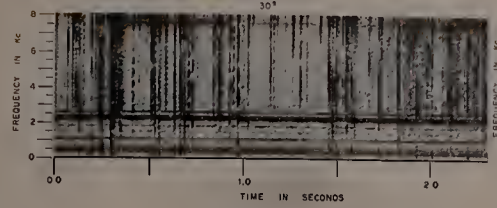

20 JUNE 1957

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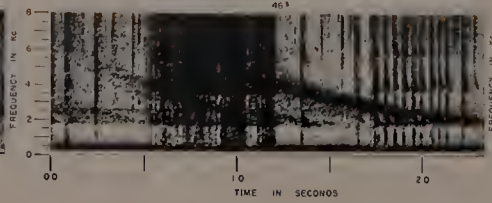

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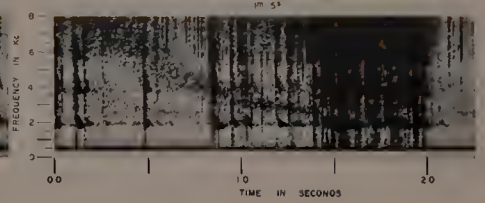

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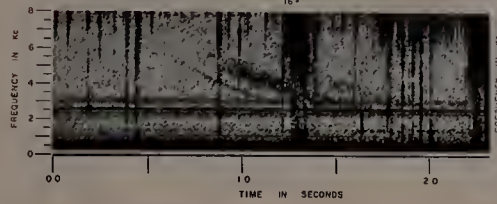

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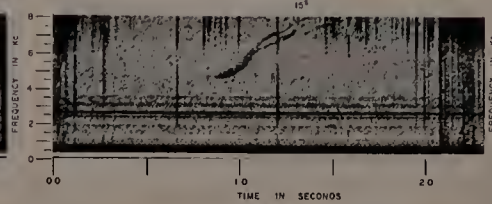

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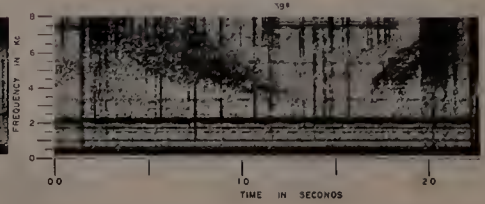

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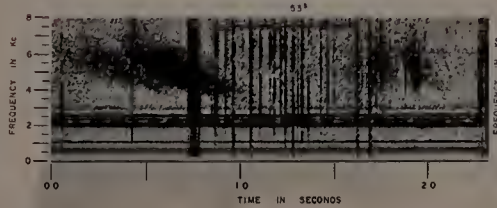
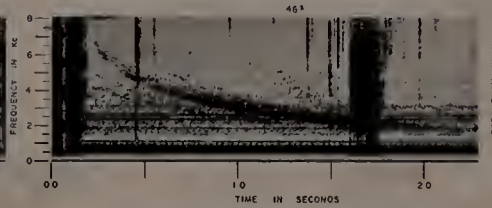


21 JUNE 1957

0835 UT



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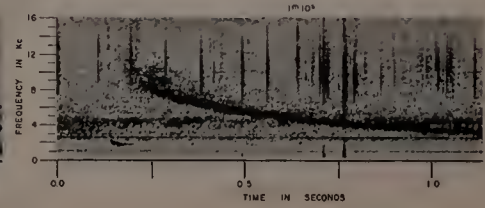

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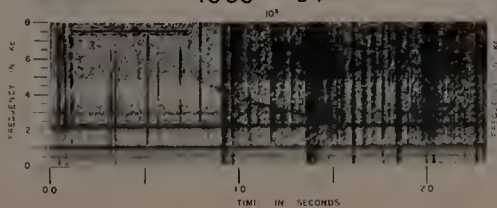
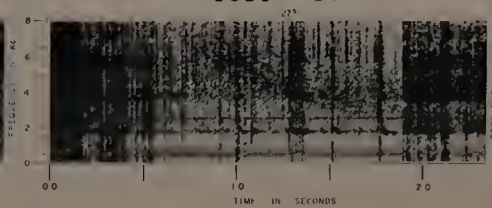


22 JUNE 1957

0935 UT



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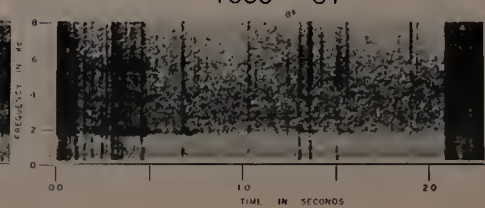
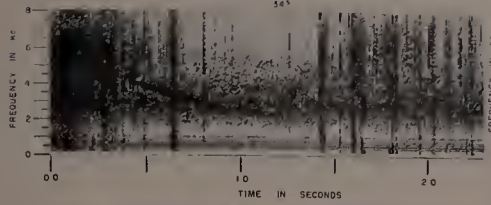


22 JUNE 1957

1135 UT



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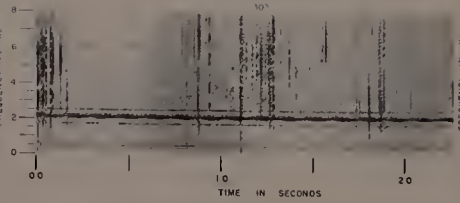

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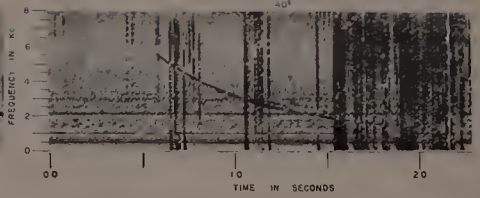
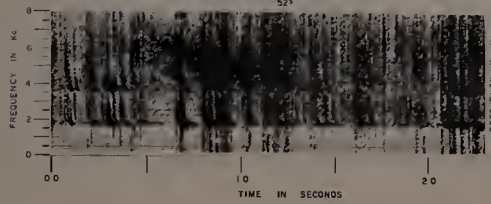


24 JUNE 1957

1035 UT



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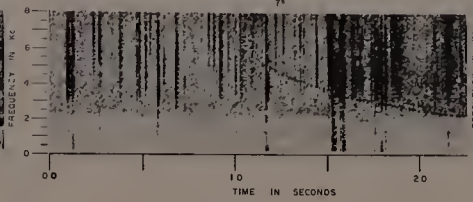

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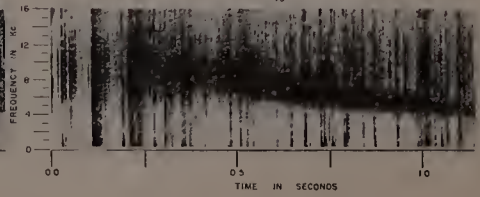

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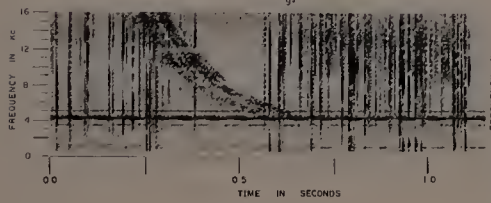
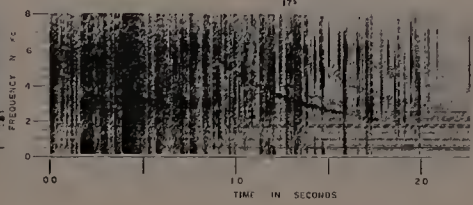


25 JUNE 1957

1135 UT



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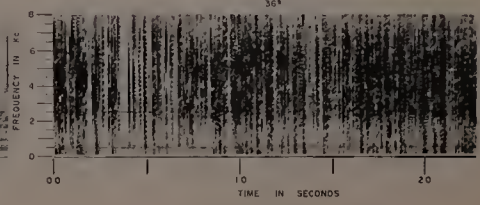

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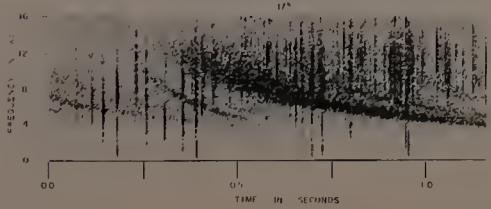

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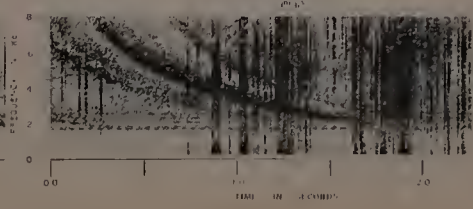

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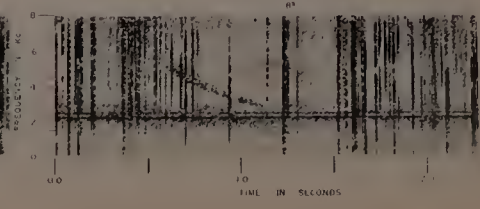

25 JUNE 1957

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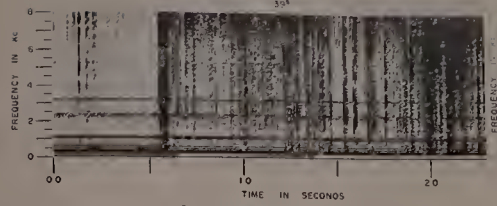

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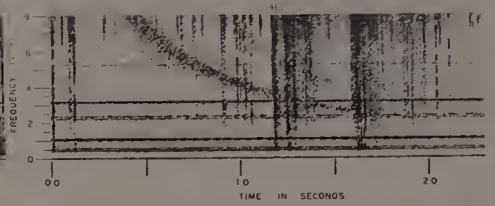

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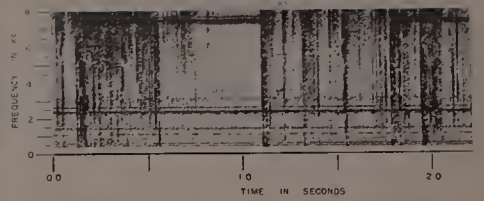
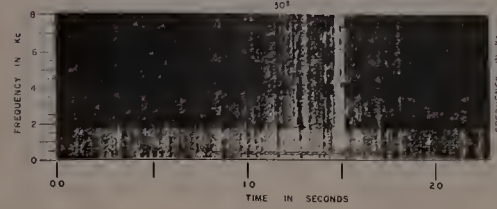
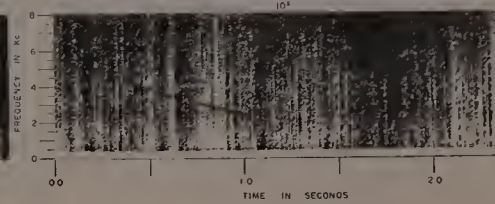


26 JUNE 1957

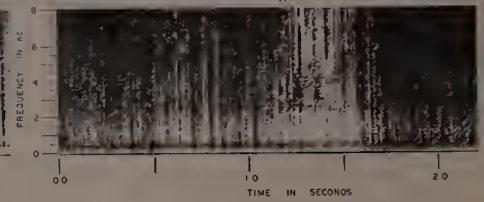
1035 UT



1135 UT



1135 UT



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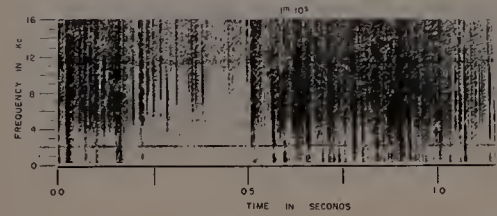
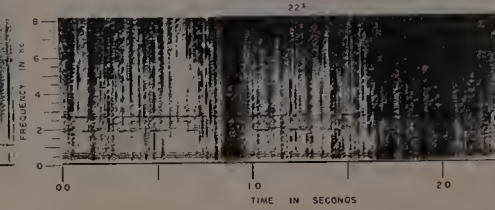
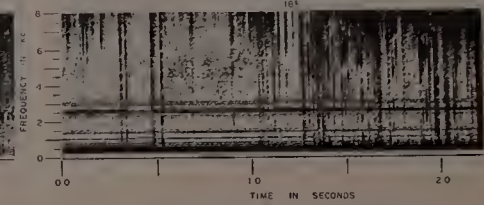


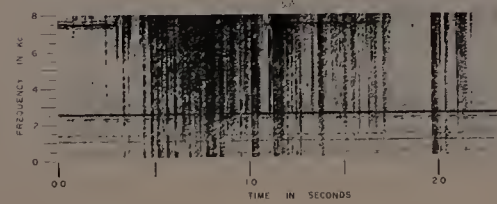
1335 UT



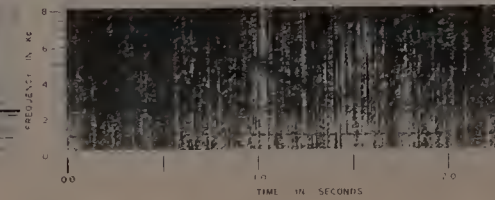
1435 UT



1535 UT

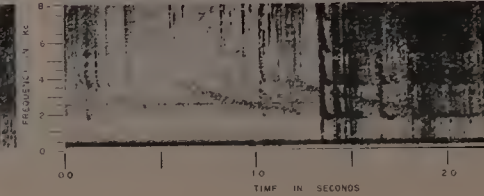


2335 UT



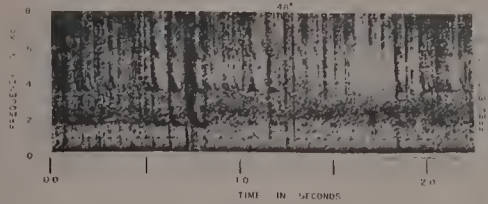
28 JUNE 1957

0835 UT

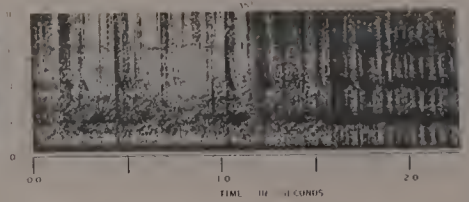


28 JUNE 1957

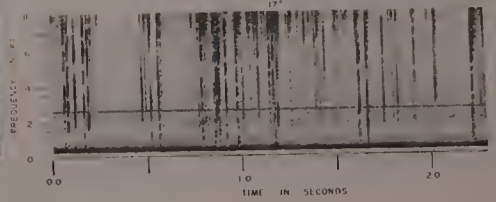
0935 UT



1035 UT



1135 UT



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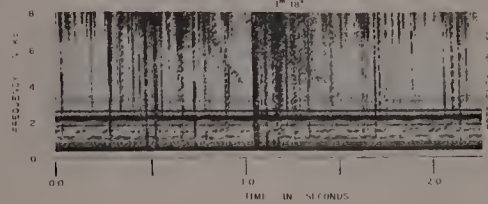

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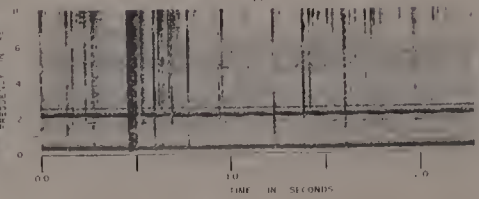
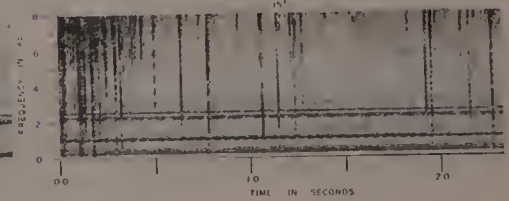
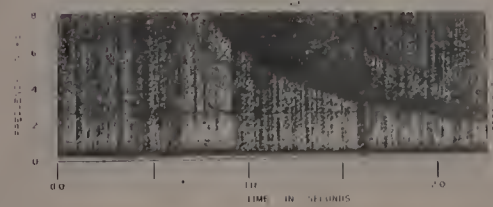


1435 UT

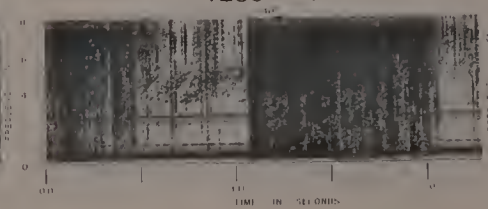


30 JUNE 1957

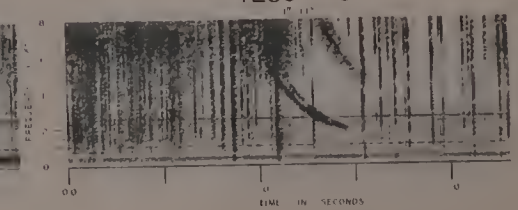
1135 UT



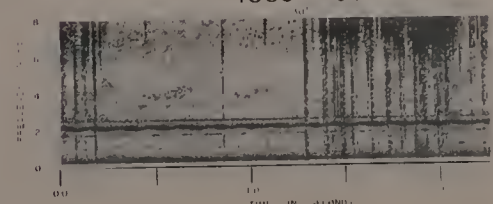
1235 UT



1235 UT



1335 UT



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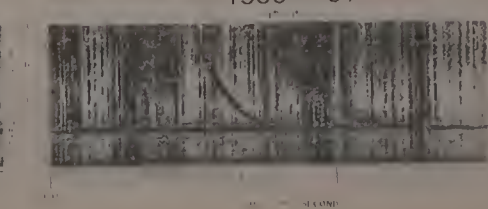

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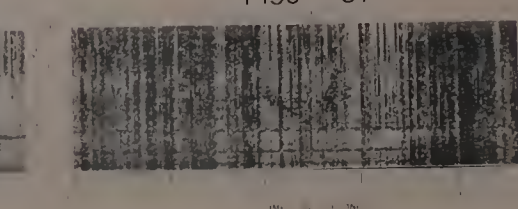
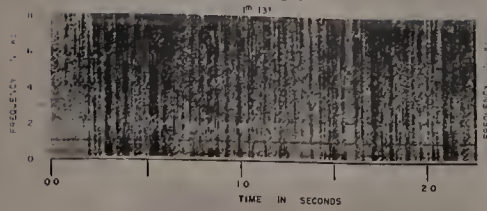


30 JUNE 1957

1435 UT



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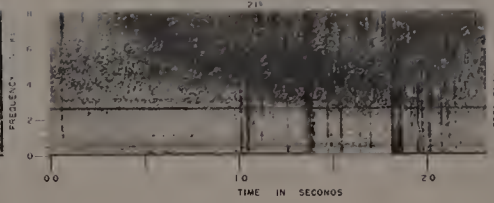

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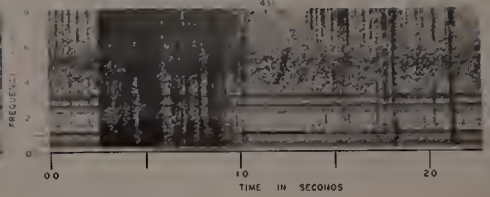
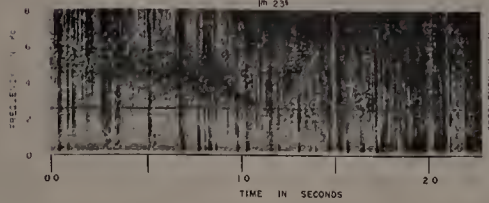
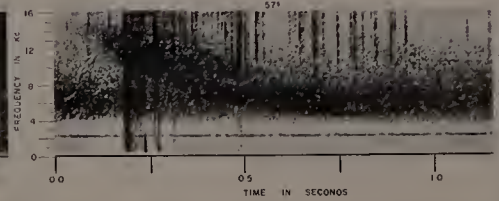


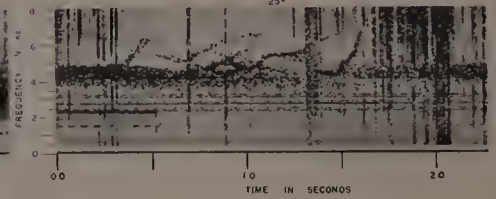
1535 UT



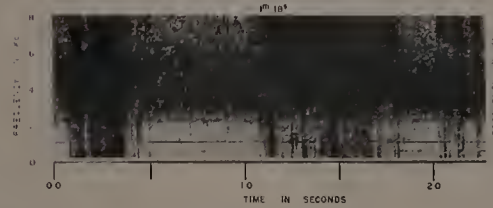
1635 UT



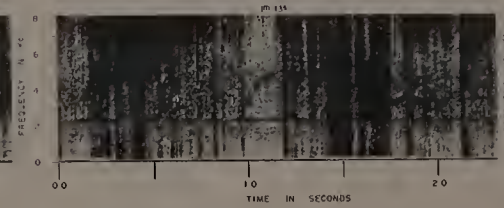
1735 UT



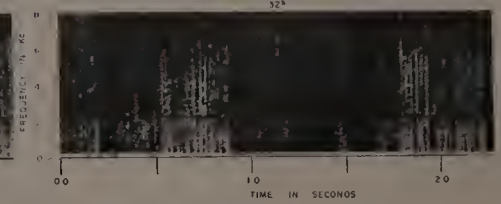
1835 UT



1935 UT

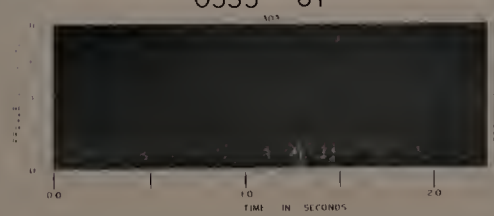


2035 UT

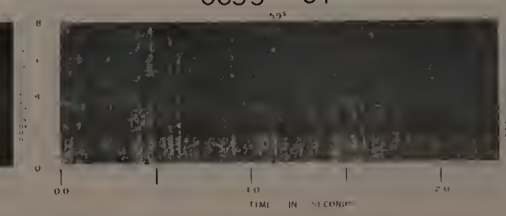


1 JULY 1957

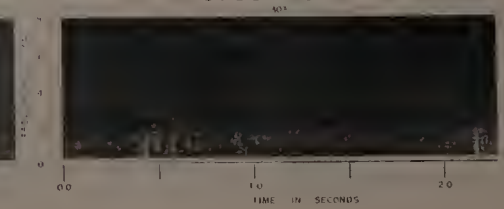
0535 UT



0635 UT



0735 UT



U. S. DEPARTMENT OF COMMERCE
Luther H. Hodges, *Secretary*

NATIONAL BUREAU OF STANDARDS
A. V. Astin, *Director*

THE NATIONAL BUREAU OF STANDARDS

The scope of activities of the National Bureau of Standards at its major laboratories in Washington, D.C., and Boulder, Colorado, is suggested in the following listing of the divisions and sections engaged in technical work. In general, each section carries out specialized research, development, and engineering in the field indicated by its title. A brief description of the activities, and of the resultant publications, appears on the inside of the front cover.

WASHINGTON, D. C.

Electricity. Resistance and Reactance. Electrochemistry. Electrical Instruments. Magnetic Measurements. Dielectrics. High Voltage.

Metrology. Photometry and Colorimetry. Refractometry. Photographic Research. Length. Engineering Metrology. Mass and Scale. Volumetry and Densimetry.

Heat. Temperature Physics. Heat Measurements. Cryogenic Physics. Equation of State. Statistical Physics.

Radiation Physics. X-ray. Radioactivity. Radiation Theory. High Energy Radiation. Radiological Equipment. Nucleonic Instrumentation. Neutron Physics.

Analytical and Inorganic Chemistry. Pure Substances. Spectrochemistry. Solution Chemistry. Standard Reference Materials. Applied Analytical Research. Crystal Chemistry.

Mechanics. Sound. Pressure and Vacuum. Fluid Mechanics. Engineering Mechanics. Rheology. Combustion Controls.

Polymers. Macromolecules: Synthesis and Structure. Polymer Chemistry. Polymer Physics. Polymer Characterization. Polymer Evaluation and Testing. Applied Polymer Standards and Research. Dental Research.

Metallurgy. Engineering Metallurgy. Microscopy and Diffraction. Metal Reactions. Metal Physics. Electrolysis and Metal Deposition.

Inorganic Solids. Engineering Ceramics. Glass. Solid State Chemistry. Crystal Growth. Physical Properties. Crystallography.

Building Research. Structural Engineering. Fire Research. Mechanical Systems. Organic Building Materials. Codes and Safety Standards. Heat Transfer. Inorganic Building Materials. Metallic Building Materials.

Applied Mathematics. Numerical Analysis. Computation. Statistical Engineering. Mathematical Physics. Operations Research.

Data Processing Systems. Components and Techniques. Computer Technology. Measurements Automation. Engineering Applications. Systems Analysis.

Atomic Physics. Spectroscopy. Infrared Spectroscopy. Far Ultraviolet Physics. Solid State Physics. Electron Physics. Atomic Physics. Plasma Spectroscopy.

Instrumentation. Engineering Electronics. Electron Devices. Electronic Instrumentation. Mechanical Instruments. Basic Instrumentation.

Physical Chemistry. Thermochemistry. Surface Chemistry. Organic Chemistry. Molecular Spectroscopy. Elementary Processes. Mass Spectrometry. Photochemistry and Radiation Chemistry.

Office of Weights and Measures.

BOULDER, COLO.

Cryogenic Engineering Laboratory. Cryogenic Equipment. Cryogenic Processes. Properties of Materials. Cryogenic Technical Services.

CENTRAL RADIO PROPAGATION LABORATORY

Ionosphere Research and Propagation. Low Frequency and Very Low Frequency Research. Ionosphere Research. Prediction Services. Sun-Earth Relationships. Field Engineering. Radio Warning Services. Vertical Soundings Research.

Radio Propagation Engineering. Data Reduction Instrumentation. Radio Noise. Tropospheric Measurements. Tropospheric Analysis. Propagation-Terrain Effects. Radio-Meteorology. Lower Atmosphere Physics.

Radio Systems. Applied Electromagnetic Theory. High Frequency and Very High Frequency Research. Frequency Utilization. Modulation Research. Antenna Research. Radiodetermination.

Upper Atmosphere and Space Physics. Upper Atmosphere and Plasma Physics. High Latitude Ionosphere Physics. Ionosphere and Exosphere Scatter. Airglow and Aurora. Ionospheric Radio Astronomy.

RADIO STANDARDS LABORATORY

Radio Physics. Radio Broadcast Service. Radio and Microwave Materials. Atomic Frequency and Time-Interval Standards. Radio Plasma. Millimeter-Wave Research.

Circuit Standards. High Frequency Electrical Standards. High Frequency Calibration Services. High Frequency Impedance Standards. Microwave Calibration Services. Microwave Circuit Standards. Low Frequency Calibration Services.

NBS